DESIGN AND DEVELOPMENT OF DATABASE FOR PROCESS PLANNING AND NC PART PROGRAM GENERATION FOR ROTATIONAL COMPONENTS

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by
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DEDICATED TO

MY PARENTS

CERTIFICATE

This is to certify that the Present work on "Design and Development of Database for Process Planning and NC Part Program Generation for Rotational Components", by Girish Thakar has been carried out under our supervision and has not been submitted elsewhere for the award of a degree.

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- GIRISH THAKAR

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NOMENCLATURE

D	Drill diameter	mm
d	Depth of cut	mm
d_m	Diameter of machined surface	mm
F_c	Cutting force	Newton
f	Feed	mm/rev
h_{max}	Maximum peak to valley height	mm
hcla	Center line average	mm
L	Length to be machined	mm
N	Rotational frequency of spindle	RPM
R	Nose radius of insert	mm
t_1	Undeformed chip thickness	mm
U_c	Specific cutting energy	N/mm^2
U_o	Constant	J/mm^3
v	Cutting speed	mm/min
W	Power	Watts
w	Width of cut	mm
β	Semi drill angle	Degree
ϕ	Toolholder approach angle	Degree

ABSTRACT

In the present thesis an attempt has been made for the design and development of a database for integrated process planning and part programming of rotational components. The system is divided into two modules, namely process planning module (Module-I) and part programming module (Module-II).

The process planning module consists of databases for operations, machine tools, cutting tools (i.e. toolholders and inserts), cutting fluids, cutting conditions, work materials, tool materials and cutting tool location on turret. The module is menu driven and each selected entity is checked for it's compatibility with the entity selected in previous menu. Finally it generates a process plan for a given operation

Part programming module receives process planning information from module-I in the integrated mode of operation. For the independent mode of operation, this information is fed externally. Additional part programming information like label of part program, desirability of coolent and coordinates of starting point of the operation is to be inputted in both the modes of operation.

Finally a part program corresponding to the operation is retrieved from the library and tagged with the relevant data for display on the CRT screen.

Attempt has been made to provide adequate help facilities in the situations of improper inputs and incompatibilities between entities. In such cases the system helps the user to select a proper input or suitable alternative.

Both the modules support general turning operations like turning, taper turning, facing, axial boring, axial boring shoulder, and thread turning and axial drilling.

The system has been implemented on an IBM PC-XT/AT compatible with DBASE III plus as database management system.

CHAPTER - I

INTRODUCTION

Recent developments in computer technology have tremendously influenced the hardware as well as decision making process in the manufacturing systems. The flexible automation is aimed at high utilization of machine tools with a flexibility to accommodate a range of part designs. Manufacturing activities carried out with the help of computer and particularly known are CAD (Computer Aided Design), CAM (Computer Aided Manufacture), CAPP (Computer Aided Process Planning), and CAQ (Computer Aided Quality Control) just to name a few.

We shall be concerned with two functions: process planning for parts and part program generation for numerical control of machine tools.

1.1 Process Planning:

Process planning is the activity that determines the appropriate procedures to transform raw materials into finished products as specified in engineering design. There are two approaches to this activity, computer aided and manual. This activity can be divided into following parts:

(a) Selection of operations

(b) Selection of machine tools

(c) Selection of cutting tools

(d) Sequencing of operations

(e) Grouping of operations

(f) Selection of work holding devices

(g) Selection of inspection instruments

(h) Determination of production tolerances

(i) Determination of cutting parameters (feed, speed and depth of cut)

(j) Determination of production cost, production time and production rate

(k) Editing of process sheet.

In the traditional approach, process planning procedure is very much dependent on the experience and judgement of the planner. Individual engineers each have their own options about what constitutes the best routing. Accordingly there are differences among the operations sequences developed by various planners. Machine breakdowns force shop floor personnel to use temporary routings. For these reasons and others, a significant proportion of the total number of process plans used in manufacturing are not optimal.

Automated process planning makes use of characteristics of a given part to automatically generate the manufacturing operation sequence. CAPP system offers potential for reducing the routine clerical work of manufacturing engineers. At the same time provides the opportunity to generate production routings which are rational, consistent and perhaps even optimal.

1.2 NC Part Programming:

Numerical control part programming is the procedure by which the sequence of processing steps to be performed on the

NC machine is planned and documented. It involves the preparation of a punched tape (or other input medium) used to transmit the processing instructions to the machine tool. There are two methods of part programming: manual part programming and computer assisted part programming.

Manual part programming is only feasible for the relatively simple parts. Most parts machined on the NC systems are considerably more complex. In more complicated parts manual part programming becomes an extremely tedious task and subject to errors. In these instances it is much more appropriate to employ the high speed digital computer to assist in the part programming process. Many part programming language systems have been developed to perform automatically most of the calculations which the part programmer would otherwise be forced to do. This saves time and results in more accurate and more efficient part program. Some of the important NC languages in current use are APT, ADAPT, EXAPT, UNIAPT, SPLIT, COMPACT II, PROMPT, CINTURN II etc. [7].

1.3 Integration of CAPP and NC Part Programming:

The need for integration of CAPP and NC part programming arises due to the fact that they share common data and information and the repetitive activities encountered in both the functions. Such an integration makes possible the better utilization of the process planners and part programmers creative potential. Therefore different research activities started to integrate CAD, CAPP and NC-programming within one system in

order to use same information repeatedly. Such existing integrated systems are differing in mode of operation - fully automatic or dialogue oriented.

1.4 Role of Database in CAPP and NC-Programming:

In order to share the same information for CAPP and NC programming, and to have a centralised control of the operational data, a database system is used.

Database is defined as a collection of operational data with least amount of repetition and stored on a computer, whose overall purpose is to record and maintain information for the use of various users and retrievable at any time.

In any manufacturing system a large amount of data including engineering data will be required by various departments at many times. The engineering database may be designed to the needs of a particular organization. Database thus designed can store, retrieve, edit, append and delete the data by means of a specialized software called - Data Base Management System (DBMS). The database systems can be conveniently categorized depending upon the data structure and associated operators supported by the system. The three best known categories are:

1. Relational Databases
2. Hierarchical Databases
3. Network Databases

The special characteristic of relational databases is that the data is in uniform manner in form of tables, which is

not shared by hierarchical and network approaches [3]. These are distributed type of databases which make possible the interaction with limited variety of information and reduce the user access to unwanted data.

In process planning and NC-programming functions, large amount of data pertaining to operations, machine tools, cutting tools, work materials, tool materials, cutting fluids and cutting conditions is required. Also many NC part programming departments have created substantial library of part programs. It is desirable to have these required data and part programs stored in well structured manner in the form of tables to facilitate easy handling and avoid duplication. The database required for any CAD/CAM system is referred to as engineering database. And depending upon the nature of data stored, engineering database consists of design database, technological database and manufacturing database.

(i) <u>Design Database</u>: At the end of the design process, the database must contain a model of artifacts stating their description. They include geometric models, bill of materials and part code.

(ii) <u>Technological Database</u>: This consists of data concerning work material (material code, composition details, hardness number etc.), manufacturing operations, machine tools (designation, and technological range of applications), cutting tools (toolholder and insert designation, specifications etc.), tool materials (ISO application grades), cutting parameters (feed, speed and depth of cut) and cutting fluids.

(iii) Manufacturing Database: This includes the information required to manufacture and assemble the part. It contains manufacturing control program and NC instructions (part program).

1.5 Literature Survey and Scope of the Present Work:

As discussed in Section 1.3, the integrated system for process planning and NC-programming shares overlapping information from a common database. The main features of such a system should be:

(a) Process Planning

- Operation sequencing
- Generation of optimum cutting conditions and surface finish data
- Selection of suitable machine tool
- Selection of suitable cutting tool and turret position
- Selection of work material
- Selection of tool material
- Selection of cutting fluids
- Calculation of cutting time and production rate.

(b) Part Programming

- Capability to share relevant process planning data
- Generation of part programs
- Interference checking of work piece and cutting tool
- Display of tool path on CRT
- Hard copy of the tool path.

The areas covered by different researchers and the scope of present study are discussed in this section.

Ravichandran et al [16] developed a software package for process planning of rotational components. This system is a stand alone system and hence does not cover the aspects of part program generation. The system uses a database for generating all the information listed in (a) but does not suggest the cutting fluid for an operation. The package has a provision to be integrated with a CAM system. Also it is able to generate the machining parameters from a database and if the user wants it can optimize these parameters.

A code software system for rotational components was developed by Haan R.A. [8]. This system stores the part programs for various part families into a database. The part programs are identified and retrieved by using a code. The coding is done on the basis of component shape to be machined by a corresponding part program, dimension range and manufacturing process used. If a particular part does not have a corresponding part program, it needs to edit one of the similar part programs of the corresponding part family. Also the user is required to select one of the many retrieved part programs. Since there is no supporting process planning module, the operational data are to be edited externally for a non existent part.

Kerry [11] has developed an integrated system for rotational components, which generates part programs and process

planning information. The part programs use GETURN system for CNC lathes. This system also has a database for selecting a suitable cutting tool, machine tool, and work material. It also calculates the optimized cutting parameters, and tool path depending upon the geometry of finished part and raw stock. Also it is automatic as well as dialogue based i.e. the automatically selected cutting conditions and cutting tools can be changed by the user. The special feature of this system is the ability to transfer special instructions to the operator through the part program and it can be integrated with MICLASS coding system for group technology.

The programs developed by this system do not contain any tool motion statements, as they are digitized and are directly fed to the user. Also there is no facility to verify the tool paths. The system does not recommend any cutting fluids for the operations.

The process planning module developed by Ramchandran et al [16] was extended by Ramchandran and Raman [15]. The automatic processing software package for CNC lathes generates a list of operations and their sequence depending upon the finished part and raw stock geometry. It receives the process planning data from the process planning module and displays the tool path on CRT screen, generates the process plan and hard copy of the tool path. Also it checks for interference of cutting tool and work material.

The above system does not generate the NC part program.

EXCAP is a prolog based expert system for process planning of rotational parts developed at UMIST [4]. This system has been restricted to determining the appropriate tools and operating sequence for NC machining. The current system uses a york portable prolog sheel which is rather slow and now being replaced by POPLOG. The sequence generation involves pattern recognition, once the patterns are recognized the most appropriate tool is selected. Selection of machining sequence is partially algorithmic as present computing power makes it expensive to use expert systems where algorithmic ones will do.

A most complete and integrated system for process planning (AUTAP) and NC-part programming (AUTAP-NC) is developed by Eversheim et al [5]. This system can cater to rotational as well as sheet metal components.

AUTAP and AUTAP-NC system requires the part description which is dissected into geometric and technological data. The position of geometric elements for rotational components is described by describing the outer contours from left to right and then the inner contours in the same manner. For sheet metal components the position of each geometric element is required to be described. This part description is stored in a centralised database.

The system can select a work material, operation sequence from network of operations depending upon shape and dimensions of part and order data.

Also there are databases for machine tools, chucks, cutting data etc. The machine tool is selected by economical and technological range of operations.

The logical generation of part programs and macros depends upon the description of finished part and raw stock. The AUTAP-NC system is capable of functioning as a stand alone system also. The integrated system can function in dialogue or Batch mode. There is also a facility for the graphical generation of the tool path which can be used for checking the sequence of operations.

Though it is a most complete system but it does not provide process planning information about tool materials, and cutting fluids. Also there is no check for the accommodability of selected cutting tool on the machine tool selected from economic and technological considerations.

From the above literature, it can be seen that the concepts of part program library and database for process planning information were not combined. Hence the present attempt has been made to combine these two ideas and generate process planning information like machine tool, cutting tool, work material, tool material, cutting time, hourly production rate, cutting conditions, cutting fluids, surface finish data and turret position. Also it was borne in mind that the generated data are compatible with each other (i.e. cutting tool work piece are accommodable on machine tool, and the selected cutting conditions are achievable on the machine tool etc.).

The generation of part programs takes place from the part program library and tagging of relevant process planning information. The system generates this data for a given operation. Also the module-II is capable of stand alone functioning.

1.6 Organization of Thesis:

System analysis is the starting block for the design and development of database for NC part program generation for rotational components.

Chapter-II is devoted to System Analysis where the system description, system development and input-output specifications are dealt with.

Chapter-III discusses the design of database which includes database design considerations, database description and structure, and database system flow chart showing interaction between various databases.

The development and implementation aspects like system flow charts and application programs are presented in Chapter-IV.

In Chapter-V conclusions are stated.

CHAPTER - II

SYSTEM ANALYSIS

We consider rotational (axi-symmetric) parts where the surfaces of revolution are to be machined. The operations included for system analysis, design and implementation are turning, taper turning, facing, axial boring, axial boring shoulder, thread turning, and axial drilling.

The system under consideration comprises a set of horizontal and inclined bed type turning centres. These turning centres have rear turrets to accommodate a limited number of cutting tools. The cutting tools for general turning (turning, facing, taper turning, axial boring and axial boring shoulder) are of right hand type. These tools can accommodate a number of insert shapes such as square, triangular and rhomboidal while the cutting tools for thread turning and axial drilling accommodate diamond and hexagonal inserts respectively.

With the above system configuration in reference an interactive software has been developed for process planning and NC part program generation. In this chapter the description of system considered, stages and steps of system development and input-output specifications are presented.

2.1 System Description:

The present software have been developed using a database management system (DBMS). The software system consists of

two modules: Module-I generates process planning information while the Module-II generates the NC part program for the seven operations listed above. The operations like turning, taper turning, facing and thread turning are subdivided into roughing and finishing categories, and they are treated as separate operations in the first module. Also axial drilling operation is considered as a roughing operation, while axial boring and axial boring shoulder are considered as finishing operations. Further there is a provision to extend the list of operations as per the requirement.

Part programming module (Module-II) receives relevant information from process planning module (Module-I). There is also a facility to update (append, edit, delete) the information regarding machine tools, work materials, tool materials, cutting fluids, toolholders and inserts generated by Module-I. The two modules are also capable of operating independently. In this mode of operation, information for part program generation are fed by the user externally. Considerations have been given to make the system user friendly by providing adequate help facilities.

The two modules are described in following subsections.

2.1.1 Process Planning Module (Module-I):

It helps the user to generate the following process planning information for a given operation:

1. Tool material, cutting fluid and work material
2. Machine tool, accommodable tool holder and insert pair

3. A range of feed, speed and depth of cut data
4. Machining time and hourly production rate [1]
5. Cutting tool turret position.

These process planning information are collectively displayed in form of a table in Appendix-D (Table D-1).

In order to meet the requirements of machining operations mentioned earlier, a set of five turning centres consisting of horizontal and inclined bed type of machines is chosen. A set of 87 cutting tools and corresponding accommodable inserts of various tool materials, to machine 20 work materials with applicable cutting fluids for various operations are also chosen. The data used for above entities were adopted from manufacturers catalogues [1, 9, 13, 17, 18, 19].

2.1.2 Part Programming Module (Module-II):

This module is developed to generate a complete NC part program. Each part program corresponding to various operations are stored in a database. Each part program is identified by a label. The part programs use macros for geometry definition, tool motion, tool description and definition of cutting conditions [10, 14]. These macros can be viewed separately by invoking an option provided for this purpose. The output of process plans (Module-I) relevant to part program generation such as speed, feed, depth of cut, turret position, tool offset, insert radius, total depth to be removed and total length to be machined can be updated suitably.

As stated earlier in the independent mode of operation the user provides these information directly. The information which is not derived from process planning and is needed for the part program such as label of operation, desirability of coolent during the operation, coordinates of starting point and semi-taper angle in case of taper turning operation is fed separately by the user. Also it should be noted for all further discussion that the relevant information for thread turning operation is pitch instead of feed, while for axial drilling operation the relevant information is drill diameter instead of insert radius and depth of cut, and total depth to be removed is same as total length to be machined.

For a given operation of a part the corresponding NC part program is retrieved from the database of part programs. The retrieved part program after tagging these relevant data is the part program for the operation under consideration. A set of part programs corresponding to the operations mentioned is stored in the database.

2.2 System Development:

In order to generate the list of available machine tools, work materials, toolholders and inserts for a given operation name or code (entered by the user) in Module-I, each of these entities are suitably coded.

2.2.1 Coding of Operations:

A seven digit heirarchical coding system is developed to identify various operations.

The first digit tells type of surface generated by the operation: R = Surface of revolution and N = Non revolutional surface.

The second digit is a subclassification of rotational or non-rotational surfaces. If the first digit is R then second digit will take a value of 1 for cylindrical surface, 2 for conical surface, 3 for helical surface, 4 for plain surface and 5 to 9 for others in this category. While if the first digit is N, then second digit will take a value of 1 for plain surface and values from 2 to 9 represent other type of surfaces.

The third digit is used to classify whether the operation belongs to roughing (third digit = 1) or finishing (third digit = 2) category.

Fourth digit gives the location of the operation in the group formed by the subclassification of the first digit i.e. if first digit = R and second digit = 1 and fourth digit = A, then it differentiates between similar operations like axial boring and axial boring shoulder.

Fifth digit gives the information about type of machine tool on which the operation can be performed (i.e. if fifth digit = 1, operation can be done only on horizontal machining centre, if fifth digit = 2, operation can be done only on turning centre, if fifth digit = 3, the operation can be done

only on vertical machining centre, if fifth digit = 0 then operation can be done on any of the above machine tools).

The sixth and seventh digits are reserved for identifying the database files where information about inserts and tool holders is stored (i.e. if sixth digit = 1 and seventh digit = 2, the insert database is INSGEO-1 while toolholder database is TLHGEO-2). In other words the sixth and seventh digit specifies the database designation where information for corresponding toolholders and inserts is stored for a set of operations. Figure 2.1 shows a schematic diagram of this coding system.

A code, for example, R11G211 indicates that the operation generates a revolutional surface, which is cylindrical, it is a roughing operation, lies at the seventh location in it's surface group, it can be performed on turning centre, insert database is INSGEO-1 and toolholder database is TLHGEO-1.

2.2.2 Coding of Machine Tools:

For suitable coding of the machine tools, a three digit coding system is evolved, where first digit tells the type of machine tool (i.e. if first digit = 1, then it is a machining centre, or if first digit = 2, then it is a turning centre). The second digit tells about the spindle position for machining centres and type of bed for turning centres (i.e. if first digit = 1 and if second digit = 1, then it is a horizontal machining centre, or if second digit = 2 then it is a vertical

machining centre, similarly if first digit = 2 and second digit = 1, it is a turning centre with horizontal bed, or if second digit = 2, then it is a turning centre with inclined bed).

While the third digit signifies the identity of machine tool in it's kind (i.e. if first digit = 2, and second digit = 2, and if third digit = 1, then it is an inclined bed type turning centre and first of it's kind on the shop floor). This coding system is further illustrated in Figure 2.2.

A code for example, 212 indicates that it is a turning centre with horizontal bed and second of it's kind.

2.2.3 Coding of Work Materials:

A very simple coding procedure is used for the work materials. Coding is done in three digits and all the digits are used to signify the location of work material in the work material database. An illustration is shown in Figure 2.3.

2.2.4 Coding of Toolholders:

The toolholders used for general turning operations (group A) are coded in seven digits. While the toolholders used used for axial drilling and thread turning (group B) are coded in four digits. For the first category, out of seven digits, the first digit is devoted for shape of insert it can support (S = square, T = triangular and R = rhomboidal shape). The second digit is used for type of operation for which it is used (T = turning and taper turning, F = facing, B = axial boring, C = axial boring shoulder).

The third and fourth digit signifies the serial number of toolholder in it's kind. The fifth and sixth digit signifies the approach angle of the toolholder. While the seventh digit goes for the type of cutting geometry for which it can be used (i.e. if seventh digit = N, then it is used for negative cutting geometry, or if seventh digit = P, then it is used for positive cutting geometry).

For thread turning and axial drilling operations the first digit tells the shape of insert the toolholder can support (i.e. if first digit = D, insert shape is diamond type while if first digit = H, then the insert shape is hexagonal or trigon).

The second digit for these operations is for the operation itself (i.e. if second digit = H, then it is for threading operation, or if second digit = D, then it is for axial drilling). While the third and fourth digits signify the serial number of toolholder in it's kind. Figures 2.4(a) and 2.4(b) illustrate the coding of threading-drilling toolholders and general turning toolholders respectively.

2.2.5 Coding of Inserts:

For this purpose two basic groups of operations (i.e. group A and B) as described in Section 2.2.4 are used. If the insert falls in category A of operations, a five digit code is given, where first digit tells about the shape of the insert (i.e. R = rhomboidal, S = square and T = triangular). The second, third and fourth digits are used to define the serial

number in it's kind. While the fifth digit tells about the type of cutting geometry where it can be used (i.e. P = positive cutting geometry and N = negative cutting geometry).

For category B of operations a four digit code was developed. Where first digit tells about the shape of the insert (i.e. D = diamond shape and H = hexagonal or trigon shape). The second third and fourth digits tell about the serial number in it's kind. Figures 2.5(a) and 2.5(b) show the above coding system for category B and category A of operations respectively.

However it should be noted that though the coding systems developed support machining centres and operations involving non-rotational components, they are not supported.

In Module-II as mentioned earlier, for each main operation (i.e. for roughing as well as finishing) there exists a main program which calls number of macros. The macros and main program are developed in APT (Automatically Programmed Tools) [2, 12]. It was observed that for each main operation, similar type of component geometries and tool motions are encountered. Therefore they are generalised and the user is only required to give the starting point of the operation. The rest of the calculations for the operation are performed by the system.

Each main program is written in such a way that till the desired depth of material is removed from the stock, the tool keeps on making number of passes. Also it is ensured that in each pass equal depth of material is removed. After the operation is over, the program stops the spindle and coolent

discharge and NC machine controller is stopped.

2.3 Input-Output Specifications:

Various inputs received and corresponding outputs generated by the system at various levels for Module-I and Module-II are specified in Table 2.1 and Figure 2.6 respectively.

Table 2.1 Input-Output Specifications for Module-I

S. No.	INPUT	OUTPUT
1	Operation name/code	Operation code/name
2	Machine tool code	Machine tool name and specification
3 a	Work material name	BHN range, work material code and composition details
3b	Work material code	Tool material grade and cutting fluid
4	Category A: Cutting geometry and approach angle of toolholder Thread turning: Pitch and nominal diameter to be threaded Axial drilling: Diameter to be drilled	Toolholder code(s) and specifications
5	Toolholder code	Message for: Accommodability on machine tool and applicability for operation Insert code(s) and specifications
6	Insert code	-
7	Work piece attributes and machining details	Message for: Accommodability of work piece on machine tool
8	-	Machining Parameters Category A: Feed(s), speed(s), depth of cut range Thread turning: Speed(s), depth of cut range Axial drilling: Feed(s), speed(s)
9	Machining Parameters	Message for: Feasibility on machine tool
10	-	Turret position of cutting tool and process plan

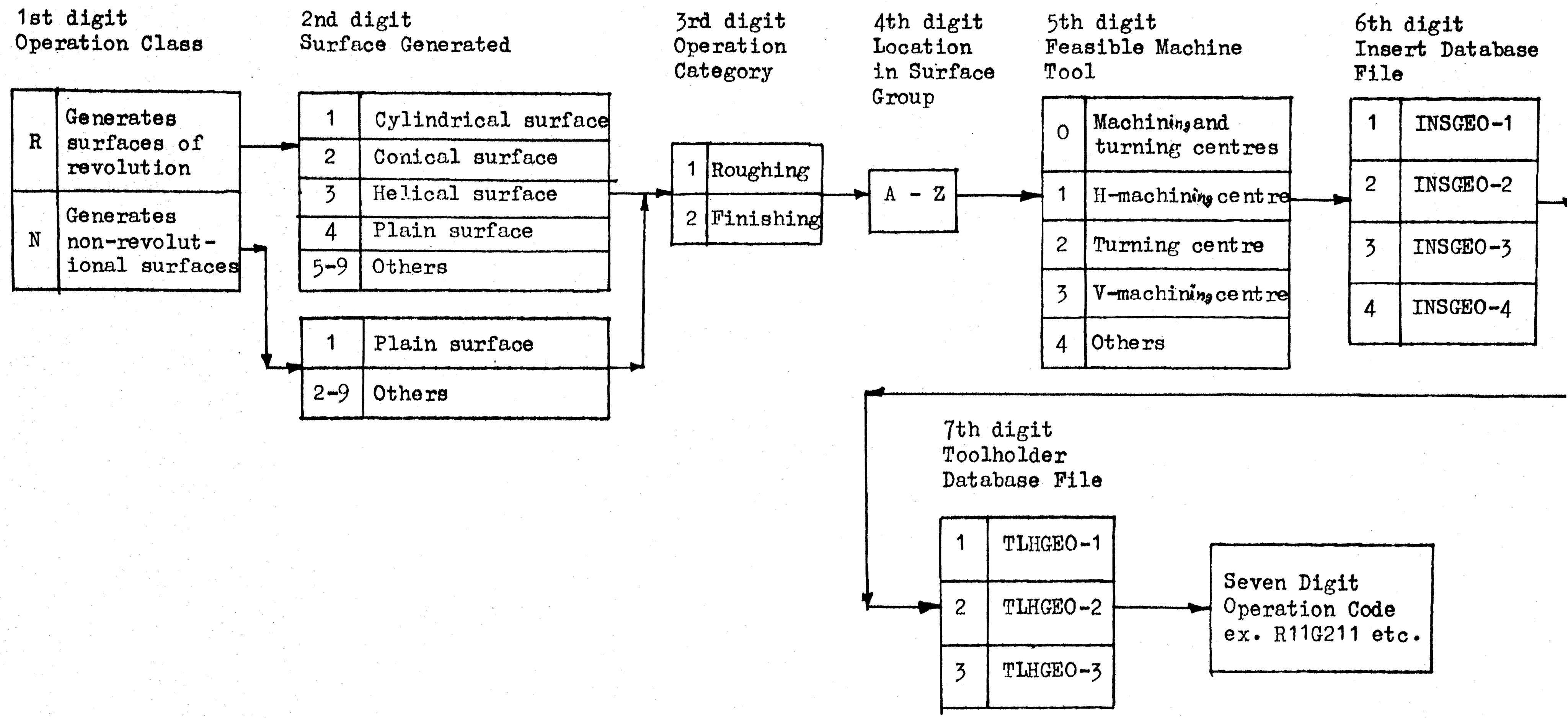


Fig. 2.1 Coding of operations.

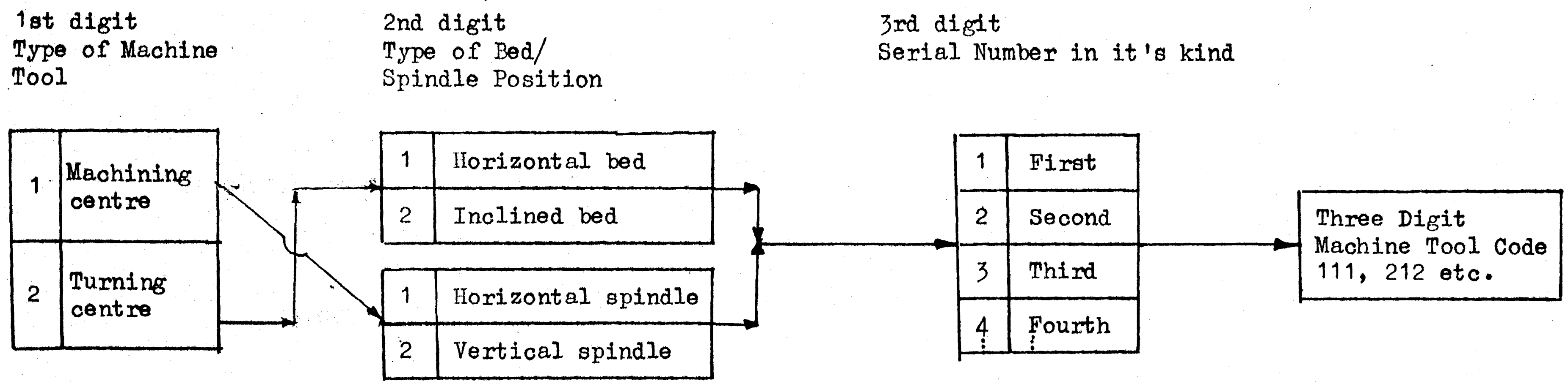


Fig. 2.2 Coding of machine tools.

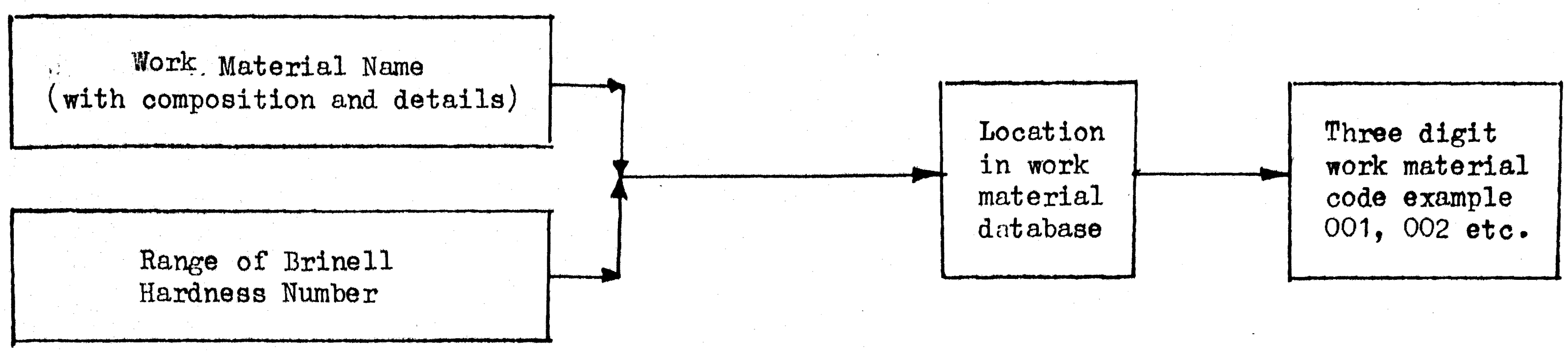


Fig. 2.3 Coding of work materials.

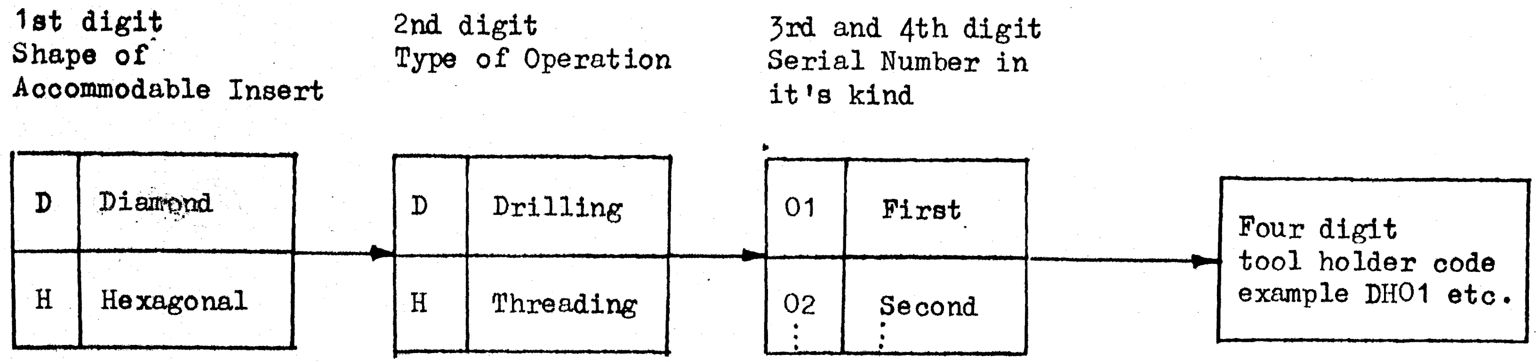


Fig. 2.4(a) Coding of thread turning and drilling toolholders.

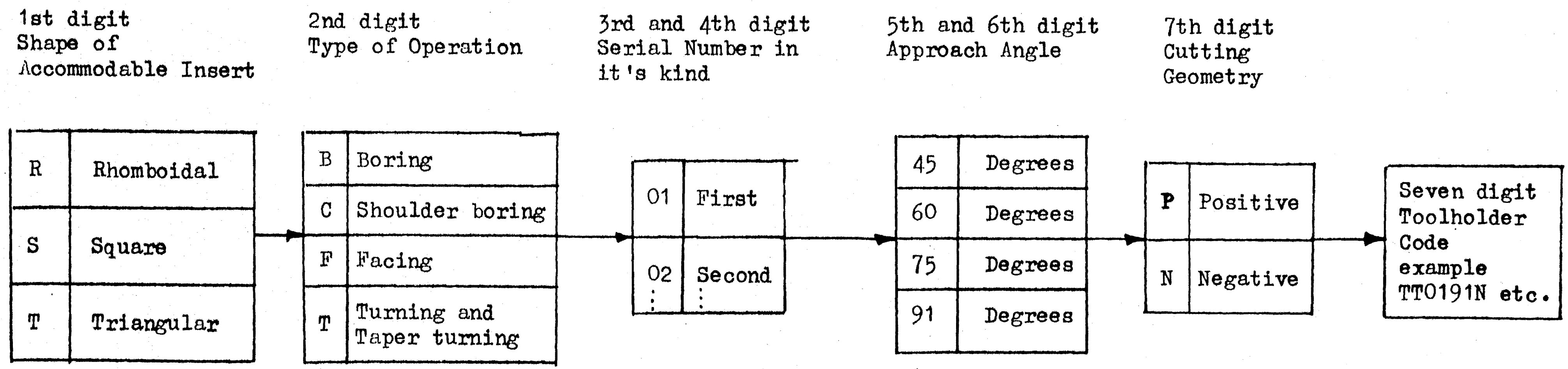


Fig. 2.4(b) Coding of general turning toolholders.

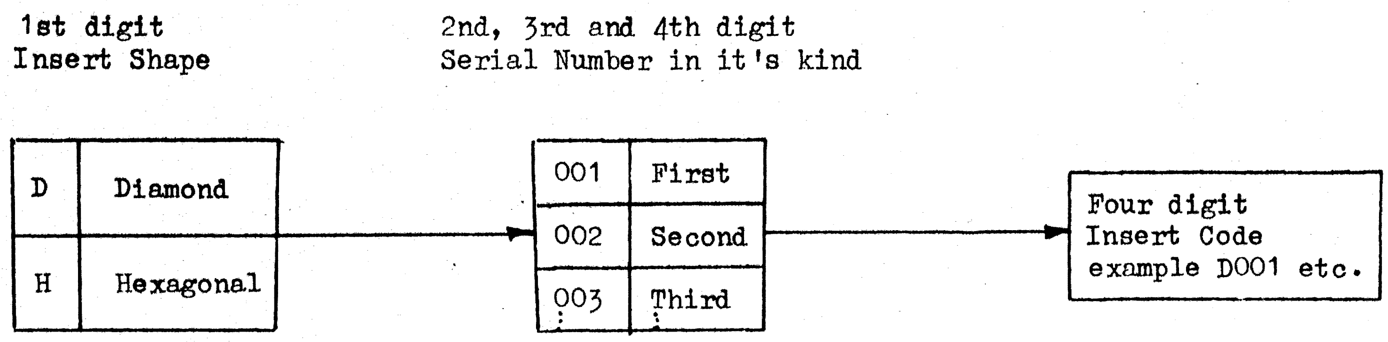


Fig. 2.5(a) Coding of inserts for thread turning and drilling operations.

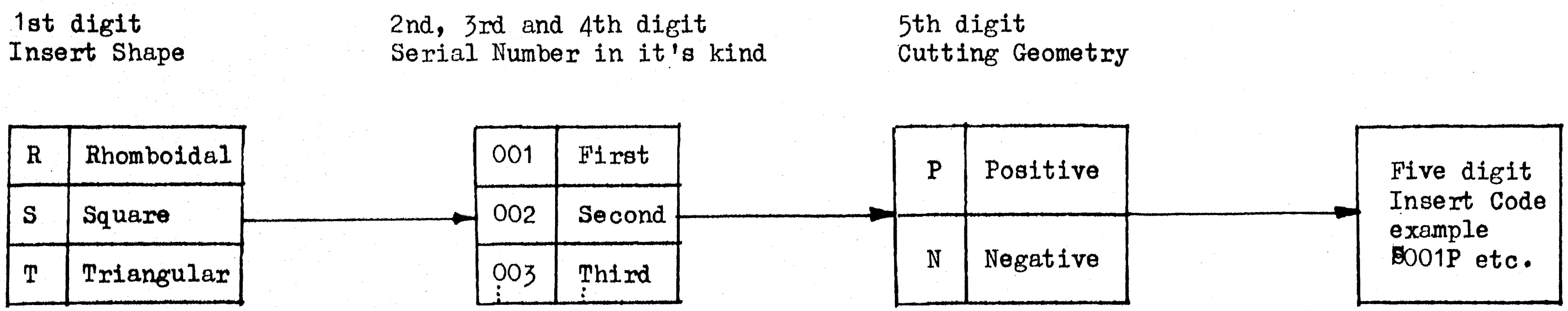


Fig. 2.5(b) Coding of inserts for general turning operations.

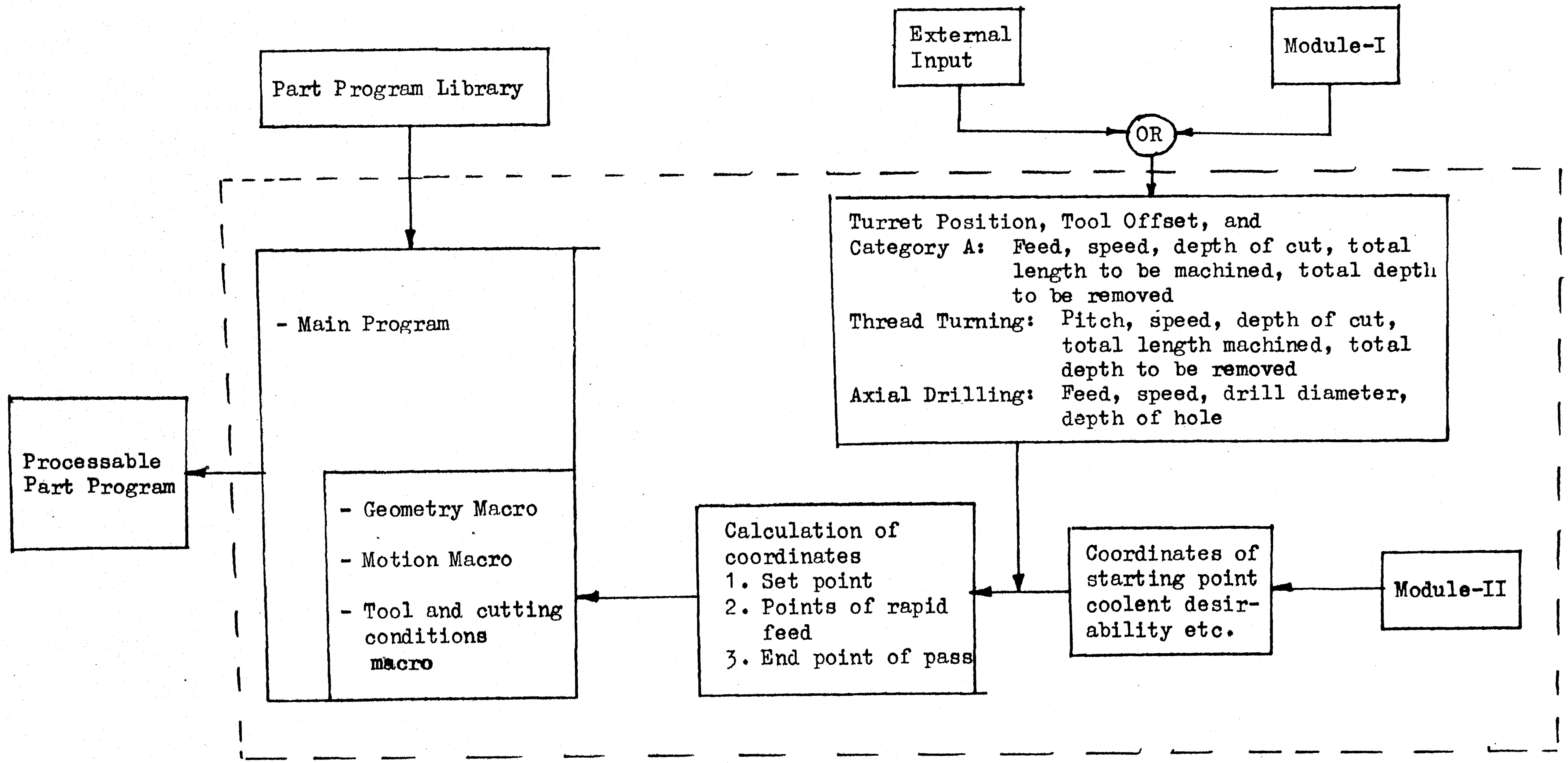


Fig. 2.6 Input-output specification for Module-II.

CHAPTER - III

DATABASE DESIGN

As described in Chapter-II, the information about machine tools, toolholders, inserts, work materials, tool materials, cutting fluids, cutting conditions, turret position and operations are retrieved from corresponding databases to generate the process plan (Module-I) for a given operation. For generating the part programs (Module-II), we have a part program library, which consists of various macros and part programs for category A and B of operations. The part program library has part programs and macros for various operations and is a database.

The design considerations, description and structures and interaction between databases are discussed in this chapter. All the databases discussed and implemented are of relational type.

3.1 Database Design Considerations:

For designing the relational databases following were considered:

(a) Primary Key

(b) The Data Items (attributes or fields)

(c) Third Normal Form of the Database

(d) Method of Searching.

These design considerations are illustrated is following example in Table 3.1.

(a) Primary Key:

Table 3.1 Relation TLHGEO-3

TLH-CODE	DIA-METER	LENGTH	NO. INSERTS	SHANK-DIA	SEMI-ANGL	TLENGTH	SIN-PHI
HD01	18	40	2	20	50	63	0.766
HD02	19	41	2	20	50	63	0.766
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.

In this database the primary key is the toolholder code (HD01). It is called a primary key, since it is an attribute with values that are unique within the relation and can be used to identify the tuples of that relation. If a combination of attributes is used for the above purpose, then the primary key is a composite key, such an example is given in Table 3.2.

Table 3.2 Relation TM-DIR

CODE	WM-CODE	ISO-AGRADE
F	001	P01-P10
R	001	P20-P40
.	.	.
.	.	.
.	.	.

In this relation the primary key is the combination of work material and type of operation (i.e. CODE = F, finishing operation and CODE = R, Roughing operation).

(b) Data Items (attributes or fields):

The consideration of data items in a relation depends upon the related information required to be retrieved with the primary key. In the earlier example (Table 3.1), for selecting a toolholder, one requires to know about the primary information like drill diameter and the length that can be drilled using this toolholder. The secondary information like shank diameter and total length of toolholder is required for checking accommodation of machine tool and calculating tool offsets respectively. While the semi-angle and sine of this angle is required for calculating the value of permissible depth of cut on the machine, using this toolholder. Hence whenever the above mentioned functions are to be performed, the relation TLHGEO-3 is used.

For the various databases used in module-I and module-II, such considerations have been given due weightage to design them.

(c) Third Normal Form of the Database:

For easy retrieval, editing and deleting records from database, it is important that they exist in the third normal form. The three normal forms are described below.

A relation is said to be in first normal form if and only if all the underlying domains contain atomic values only. While the relation is in second normal form if and only if it is in 1NF and every non key attribute is fully dependent on primary key.

Now, a relation can be said to be in third normal form if and only if it is in 2NF and every non key attribute is non-transitively dependent on the primary key [3]. The example of third normal form is given in Table 3.1, where all the attributes in toolholder database exist at an atomic level (i.e. length, diameter etc. cannot be split any further), all the attributes depend upon the primary key which is toolholder code. This dependence is a full functional dependence and there can be no other primary key in this relation.

(d) <u>Method of Searching</u>:

For searching a database, there are two methods: Random searching and indexed searching. In case of random searching, all the data records are searched from the top for a pre-stated condition while in case of indexed searching, the database is already arranged in a sequence defined by the user. For searching an indexed record, the retrieval is direct since the location of record is already known to the database.

For the process planning module, this consideration is given due importance, since the indexed searching is a better and faster method of data retrieval.

3.2 Database Description and Structure:

The structure and description of various databases has been discussed here. Appendix-B should be referred for the detailed structure.

Process Planning Module:

This module has following databases:

1. Operation Database (OPN-DIR, INDEX OPN-NAME, OPN-CODE)
2. Machine Tool Database (TRN-SPE, INDEX TCN-CODE)
3. Work Material Database (WM-DIR)
4. Tool Material Database (TM-DIR, INDEX, TM-DIR)
5. Toolholder Database (TLHGEO-1, TLHGEO-2, TLHGEO-3 and TLHGEO-9)
6. Insert Database (INSGEO-1, INSGEO-3 and INSGEO-6)
7. Cutting Condition Databases (MCDATA-1, MCDATA-3 and MCDATA-9)
8. Cutting Fluid Databases (CUTF-129 and CUTF-3)
9 Turret Position Databases (INMG-POS and EXMG-POS).

1. Operation Database: This database (OPN-DIR) contains the list of operations (category A and B) and their corresponding codes. This database is indexed on both the attributes (i.e. OPN-NAME on operation name and OPN-CODE on operation code). The primary key can be operation name or operation code and the search for it is faster. The database exists in third normal form.

2. <u>Machine Tool Database</u>: This database (TRN-SPE) is having the fields like machine tool code, and the specifications of the machine tool. The specifications of the machine tool include the centre to centre distance, swing over bed and carriage, speed and feed limits, obtainable accuracy, number of external and internal tools supported by the turret, the shank size of toolholder permissible on machine tool and the type of bed etc. The primary key is the machine tool code. The database is indexed on the machine tool code (TCN-CODE), so that retrieval of a machine tool record can be faster. It exists in the third normal form.

3. <u>Work Material Database</u>: The work material database (WM-DIR) has attributes like work material code, work material name with composition details and BHN range. The primary key is work material name. This field has not been indexed since the user inputs only a string contained by the key. Depending upon the string various records are displayed. It exists in the third normal form.

4. <u>Tool Material Database</u>: Tool material ISO application grade, work material code and category of operation (roughing or finishing) are the attributes of this database (TM-DIR). This database has a primary composite key containing category of operation and work material code. The database has been indexed (TM-DIR) on composite key with operation category as primary key and work material code as secondary key. It exists in third normal form.

5. <u>Toolholder Database</u>: There are four toolholder databases,

TLHGEO-1 for turning, taper turning and facing operation, TLHGEO-2 for boring operations, TLHGEO-3 for drilling operation and TLHGEO-9 for thread turning operation. Primary key is the toolholder code. The searching in these databases is random. The other attributes are the specifications of the cutting tool. These databases exist in third normal form.

6. Insert Databases: There are three insert databases, INSGEO-1, INSGEO-3 and INSGEO-6. The primary key is the toolholder code, while the other attributes are the insert code and insert specifications. These databases are not indexed. INSGEO-1 contains insert data for general turning operations, INSGEO-3 has insert data for drilling, and INSGEO-9 has insert data for thread turning operation.

It should be noted that INSGEO-6 also contains the permissible value of depth of cut, since in case of threading operations this attribute is linked with inserts unlike general turning toolholders where the permissible depth of cut is governed by the toolholders. For drilling operation, the considered drill toolholder and insert pairs are capable of drilling holes through solid plates. The databases exist in third normal form.

7. Cutting Condition Databases: There are three such databases. MCDATA-1 contains the attributes like Feed-1, feed-2 and feed-3 similarly there are three attributes for speed (i.e. speed-1, speed-2 and speed-3). There is also an attribute for the recommended range of depth of cut. MCDATA-3 has four

attributes for speed and one attribute for feed, while MCDATA-9 has only two values of speed.

In all the three databases, the primary key is a combination of work material code and tool material grade and the data are recommended by the manufacturers. It exists in third normal form.

8. <u>Cutting Fluid Databases</u>: There are two cutting fluid databases, CUTF-129 is used for general turning and threading operations while CUTF-3 is used for drilling operation. They contain the name of recommended cutting fluid for a work material code. The work material code is the primary key. It has a random search and the third normal form.

9. <u>Turret Position Databases</u>: There are two such databases. INMG-POS is used for the operations requiring internal tools while EXMG-POS is used for the operations requiring external tools. These databases have machine tool code, toolholder code, insert code, tool material grade and turret slot number as attributes.

This database is used for retrieving the slot position in turret where selected cutting tool is located. The primary key is a composite key consisting of machine tool code, toolholder code, insert code and tool material grade. The search is random and the database is in third normal form.

Part Programming Module:

This module contains only part program database. The part program database has the operation code as primary key. There are four part programming attributes, three of which contain macros for defining tool motion, work piece geometry and tool geometry and cutting conditions. The fourth attribute contains the NC part program which calls the above mentioned macros. These entities exist independent of operation category (i.e. roughing and finishing) since they do not have any bearing in this module.

The databases have DBF as extension and indexes have .NDX as extension.

3.3 Database System Flow Chart:

The interaction between the databases discussed earlier, for the purpose of data retrieval is shown in Figure 3.1, the appending/editing of information is shown in Figure 3.2, while the deleting of data records is depicted in Figure 3.3.

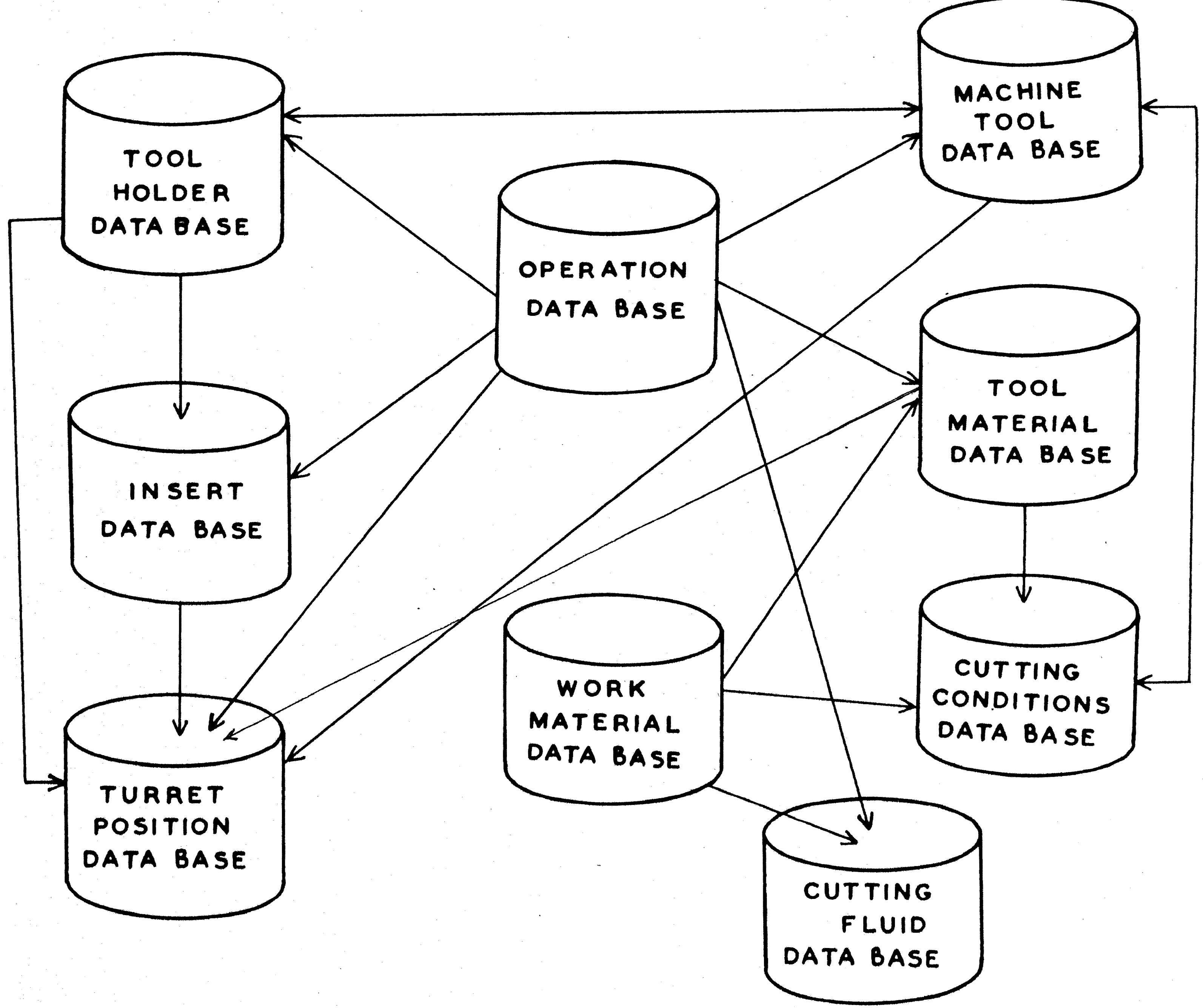


Fig. 3.1 Module-I Data base Interaction for Data Retrieval.

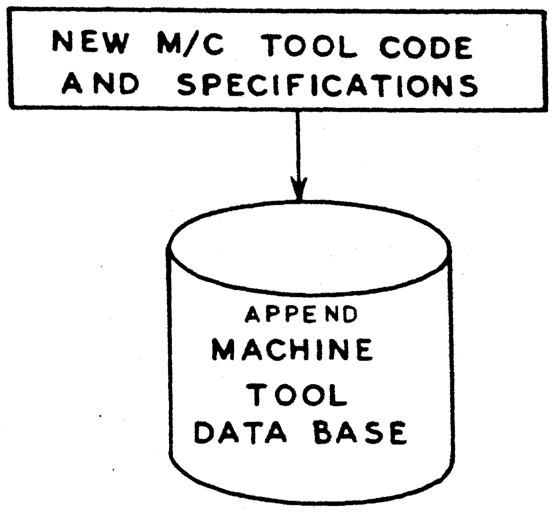


Fig. 3.2 (a)

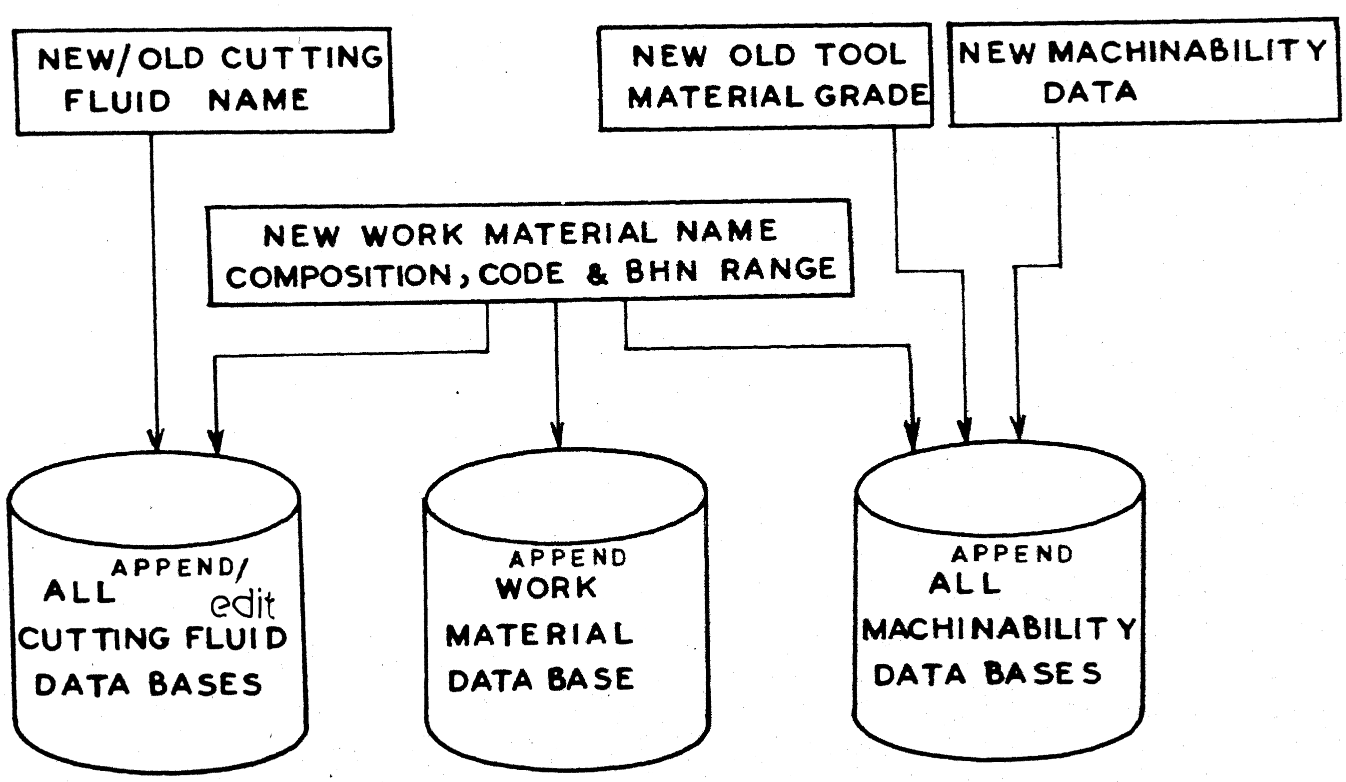


Fig. 3.2 (b)

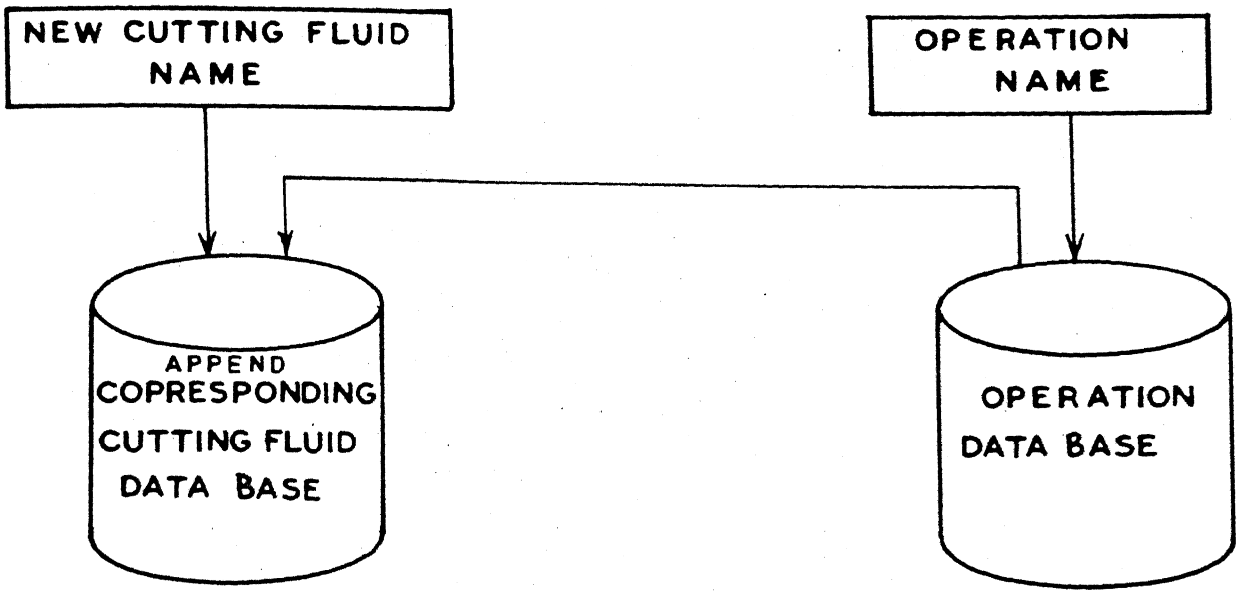


Fig. 3.2 (c)

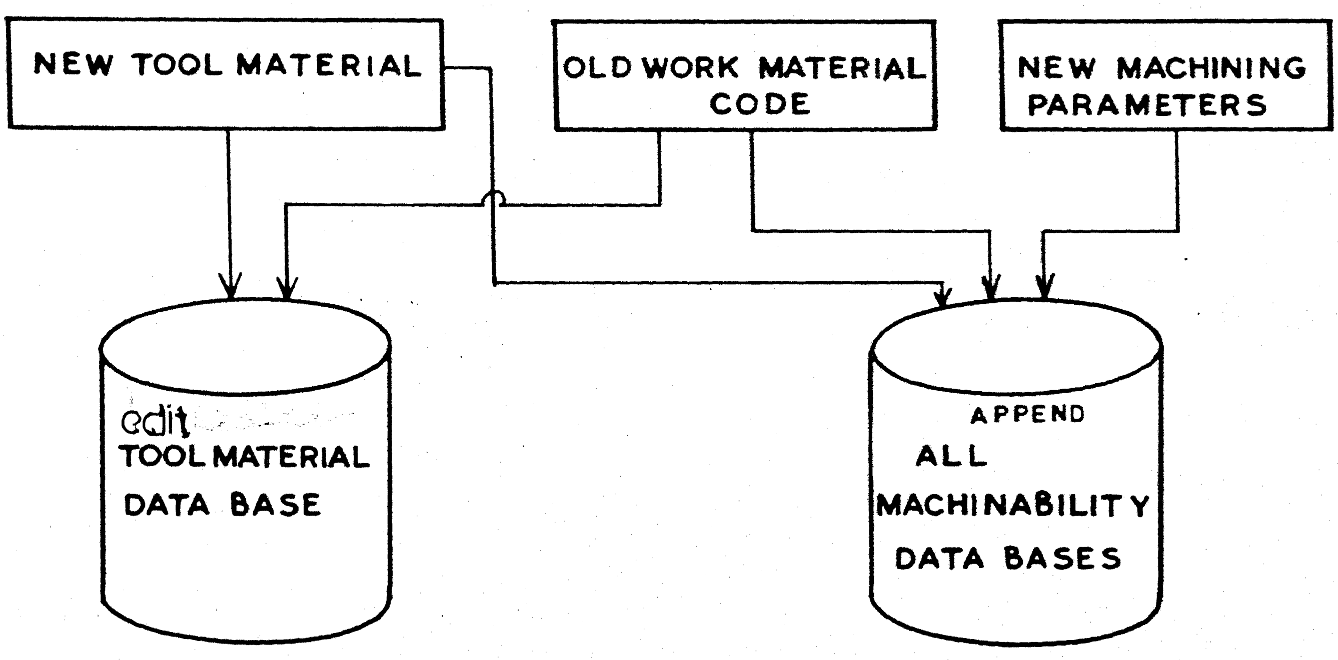


Fig. 3.2 (d)

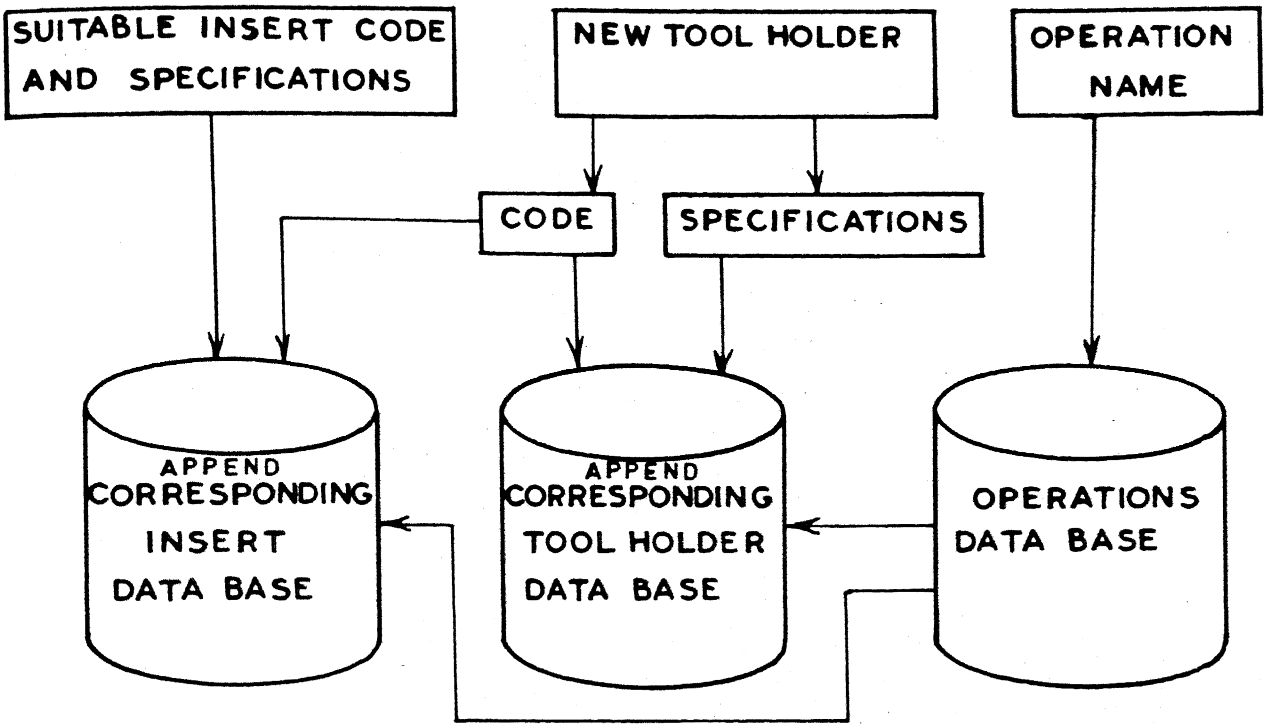


Fig.3.2(e)

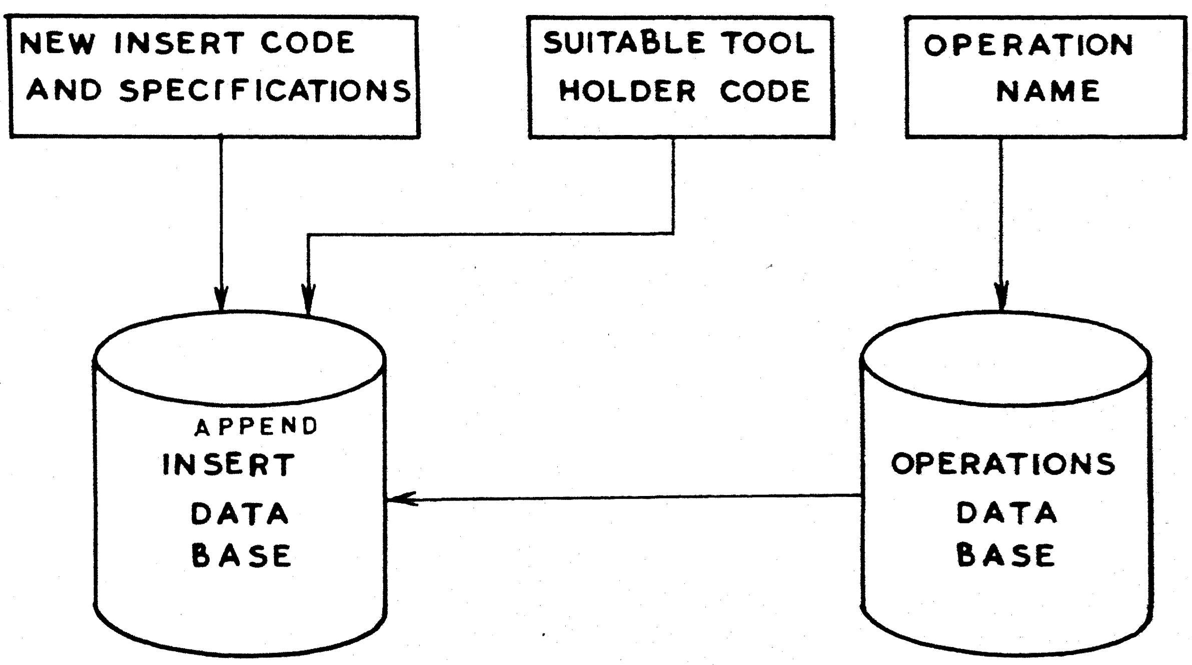


Fig.3.2(f)

Fig.3.2(a,b,c,d,e,f) Appending Editing Data base Information.

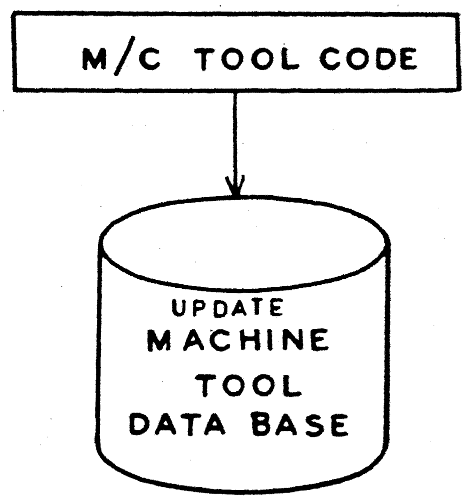


Fig. 3.3 (a)

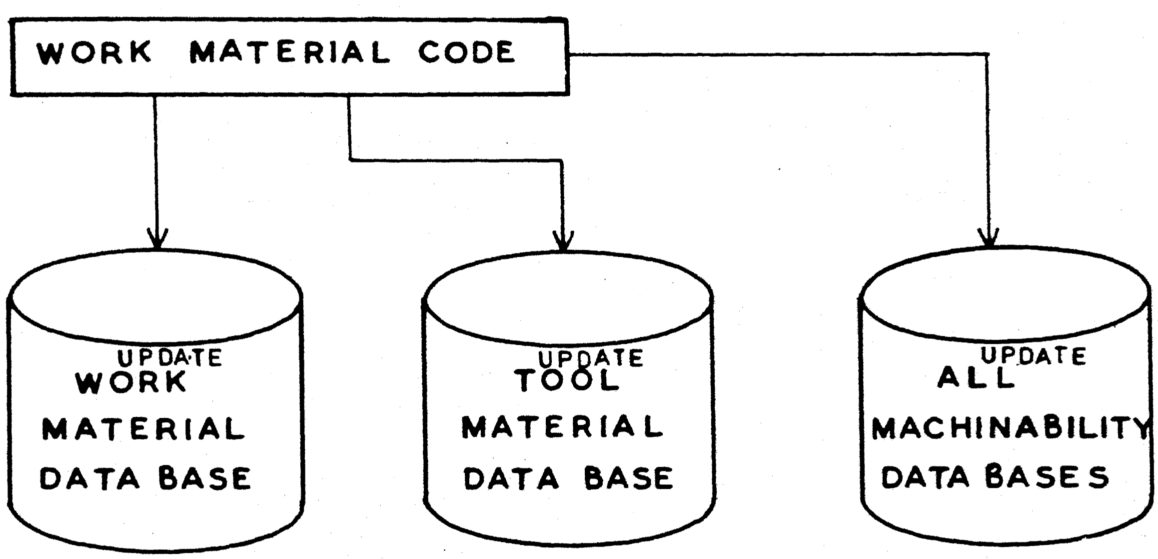


Fig. 3.3 (b)

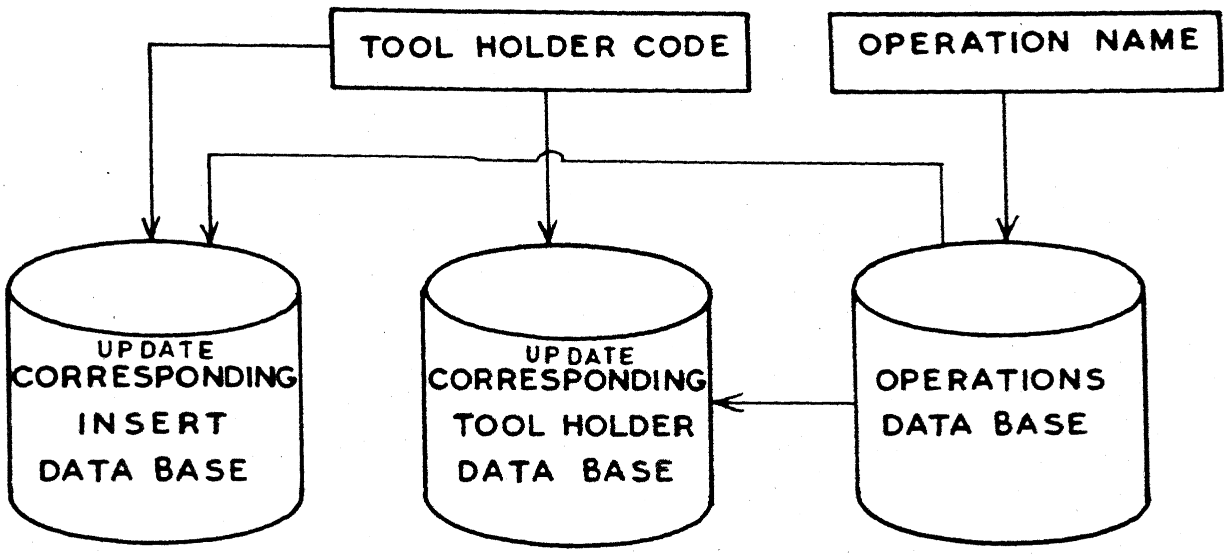


Fig. 3.3 (c)

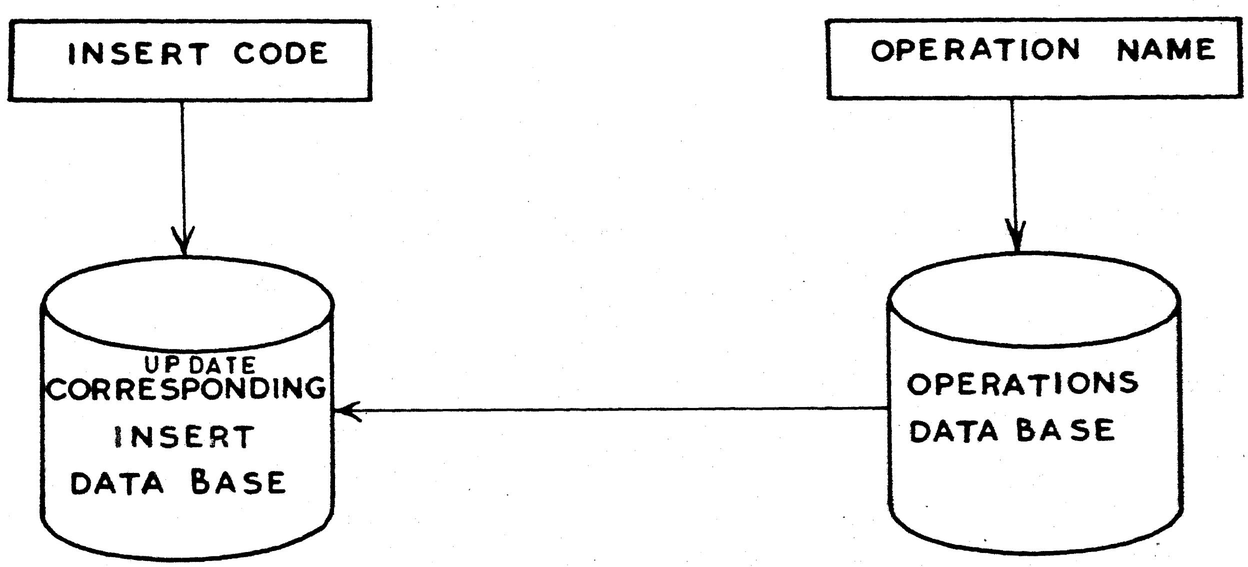


Fig. 3.3 (d)

Fig. 3.3 (a,b,c,d) Deleting Data Records From Data bases.

CHAPTER - IV

IMPLEMENTATION

The system has been implemented on an IBM PC-XT/AT Compatible, using DBASE-III plus as a database management system. The use of DBMS makes the system interactive in nature. The complete software contains database files, application and updating programs. The main features of DBASE-III plus [20] are described in Appendix-A and a user's manual has been provided in Appendix-E.

4.1 System Flow Chart:

As described in Chapter-II, the system has been divided into two main modules and two additional modules for appending/editing database files and deleting records from these files.

Master flow chart for Module-I is described in Figure 4.1, for Module-II the master flow chart is given in Figure 4.2. For appending/editing and deleting records from databases the flow charts are shown in Figure 4.3 and Figure 4.4 respectively. The programs of Module-I have been depicted in Figures 4.5 through 4.11, while the programs of Module-II are shown in Figure 4.12.

4.2 Application Programs:

Various application programs and their functions in Module-I, Module-II, module for appending/editing and module

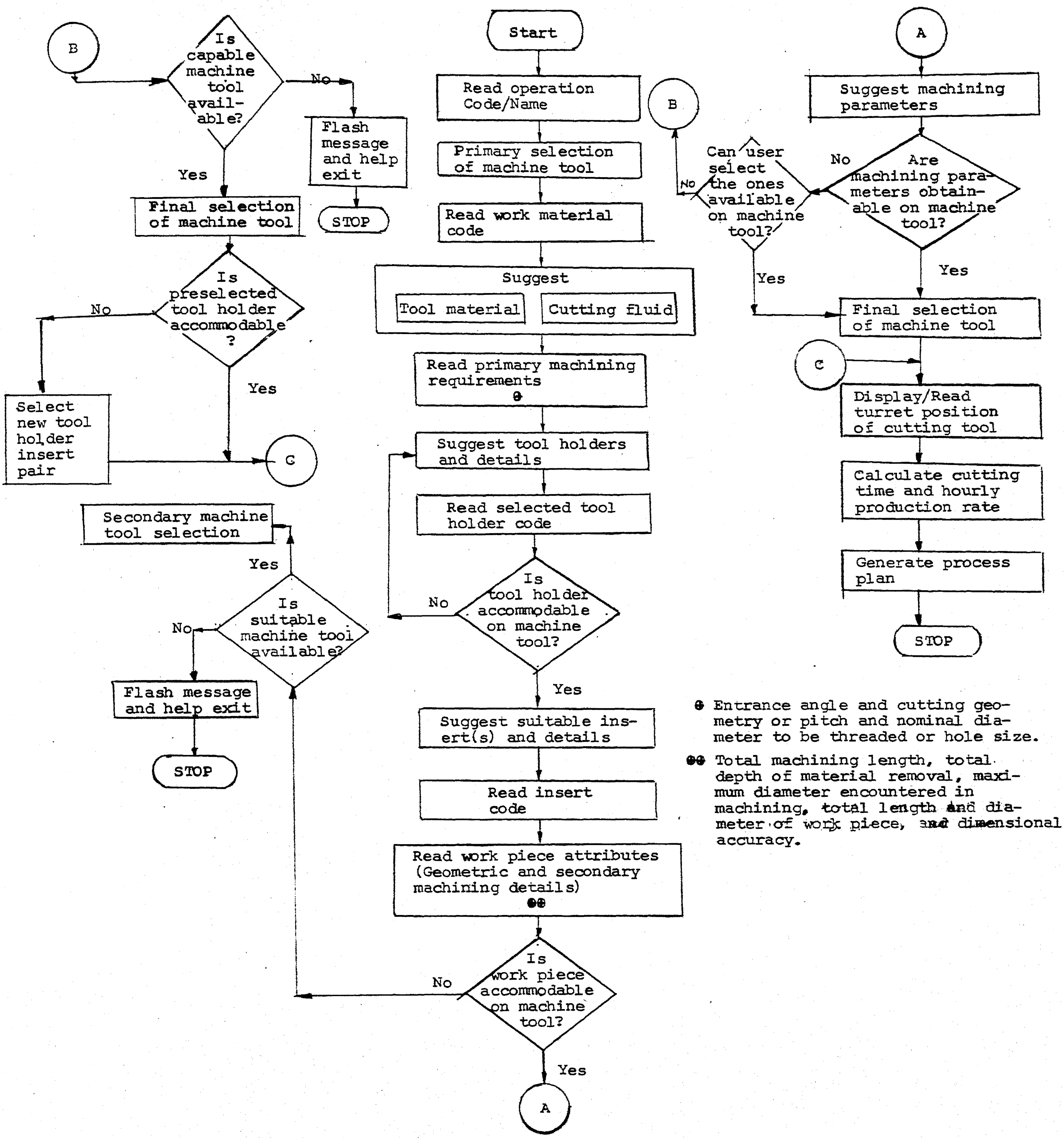


Fig. 4.1 Master flow chart for Module-I.

for deleting records have been discussed separately in following subsections.

4.2.1 Module-I:

This module has the submodules shown in Figure 4.5 and the sample outputs are given in Appendix-D of the thesis.

Main Menu (MENU Prg.):

This program displays the menu options listed in Figure 4.5 (i.e. from a to j) and also it receives a choice from 1 to 10 to execute various functions of module-I (Figure 4.1).

(a) Selection of Operation (RET2.Prg): This program receives an operation name or operation code from the user. It also verifies the selected operation with the operations supported by the operations database. If an operation entered by the user is not found in the operations database, the list of all the operations is displayed. In case the operation is misspelt the user can recall the complete name of the operation from the list of operations. Proper name of the operation is a must for this submodule (Figure 4.5).

(b) Primary Selection of Suitable Machine Tool (RET3.Prg and RET4.Prg): RET3.prg is a program which displays a list of available machine tools from the machine tool database for a given operation. The user selects using the machine tool code one of the machine tools and the corresponding name of the machine tool is displayed. When the user is with a machine tool,

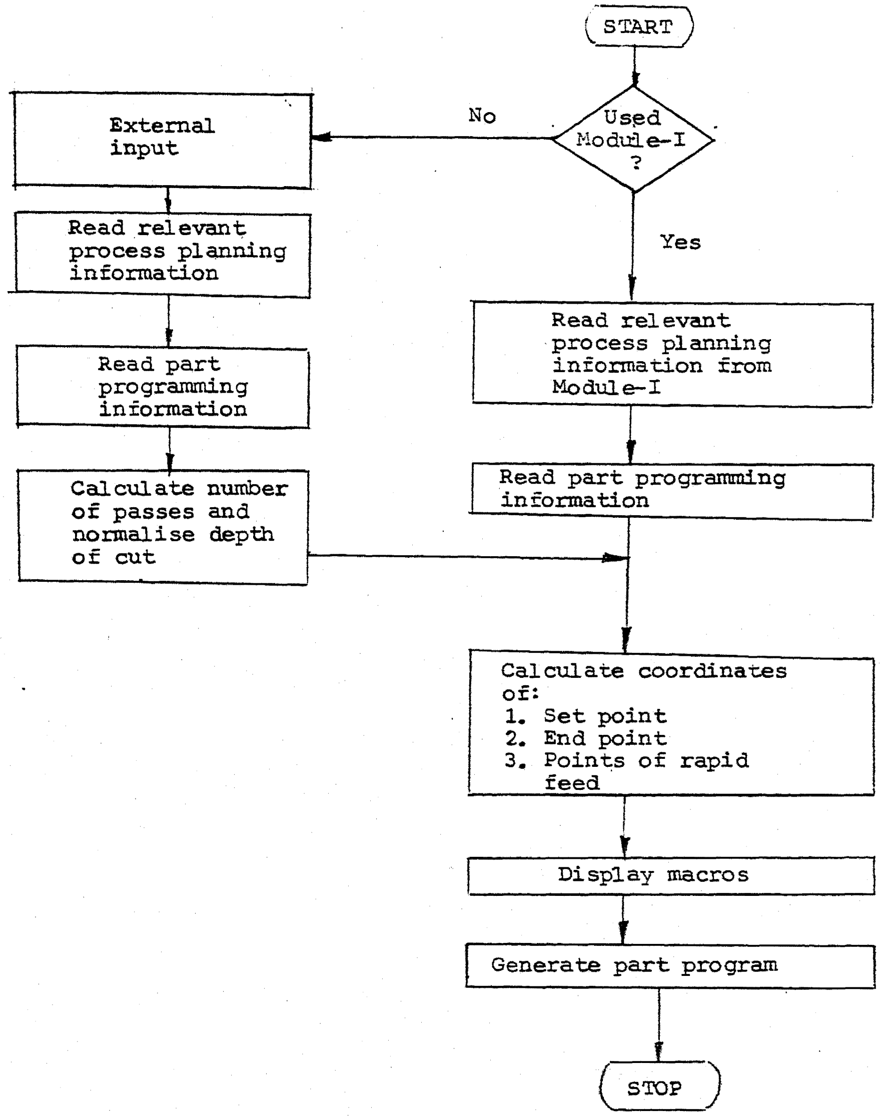


Fig. 4.2 Master flow chart for Module-II.

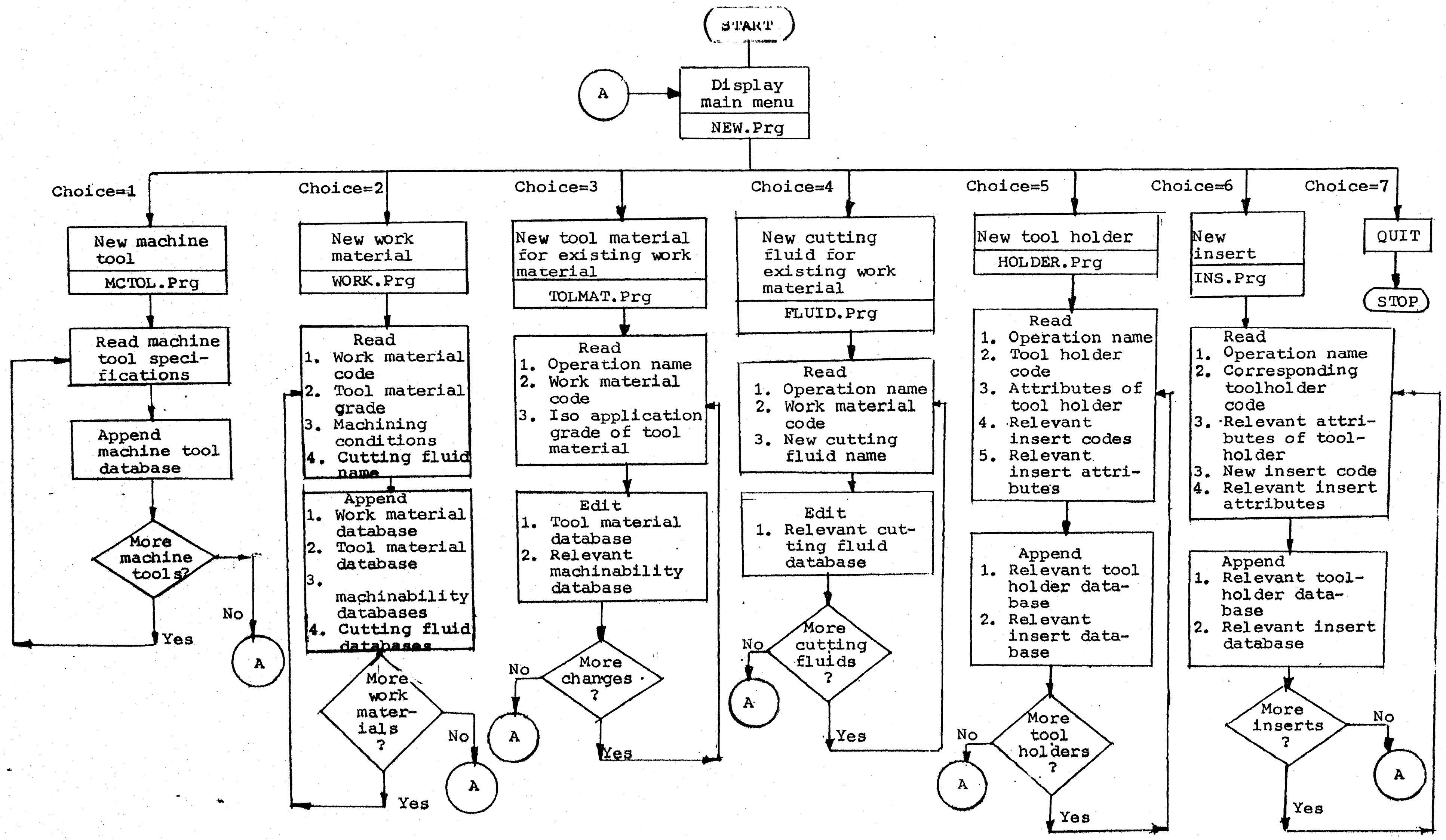


Fig. 4.3 Master flow chart for editing and appending databases.

(contd...)

A

Choice	S. No.	Appending/Editing databases (Main Menu (NEW.Prg))	Program(s)
1	a	Appending for new machine tool	MCTOL.Prg
2	b	Appending for new work material	WORK.Prg
3	c	Editing for new tool material for machining existing work material	TLCMAT.Prg
4	d	Editing for new cutting fluid for machining existing work material	FLUID.Prg
5	e	Appending for new toolholder	HOLDER.Prg
6	f	Appending for new insert	INS.Prg
7	g	Quit	-

EXIT

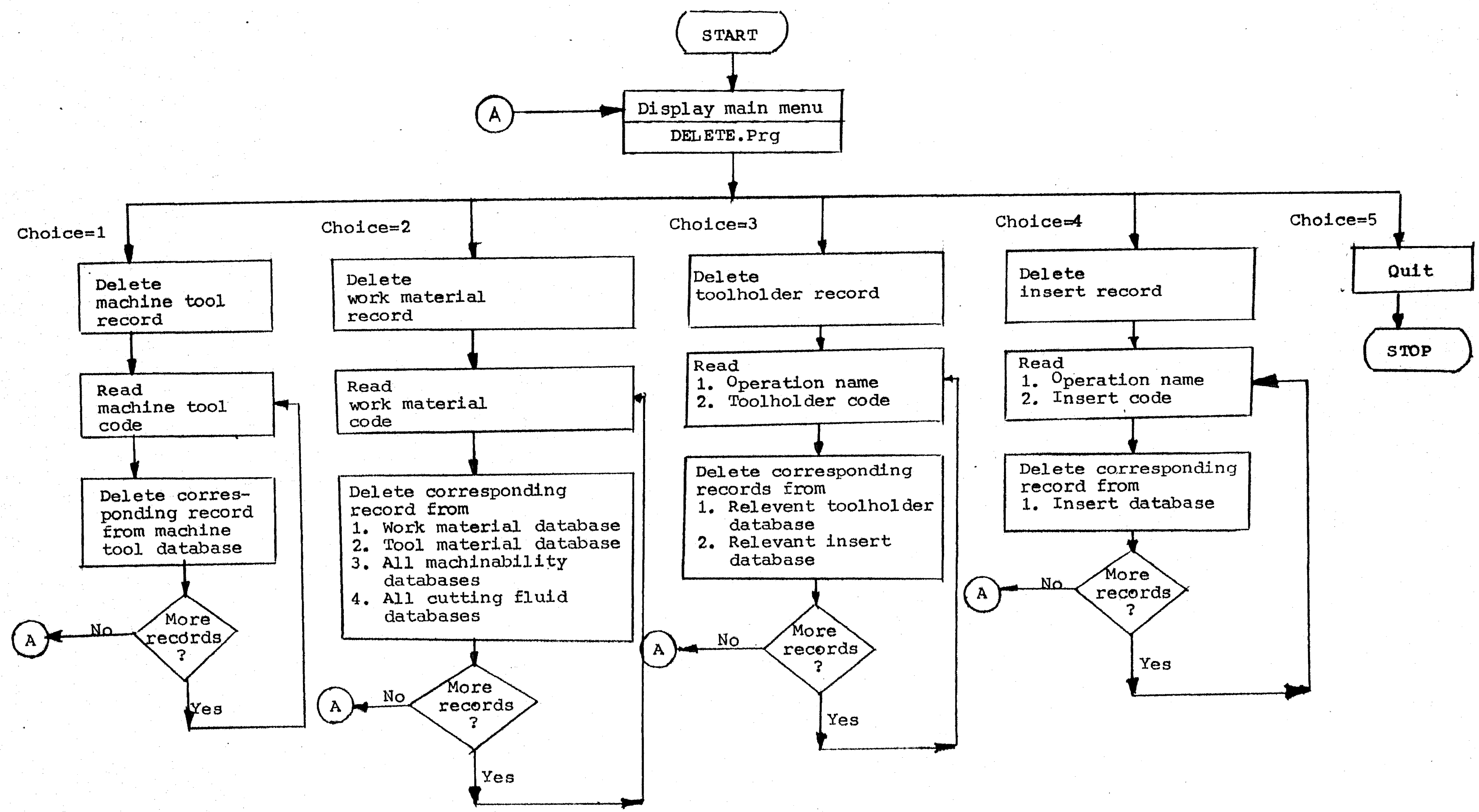


Fig. 4.4 Master flow chart for deleting database records.

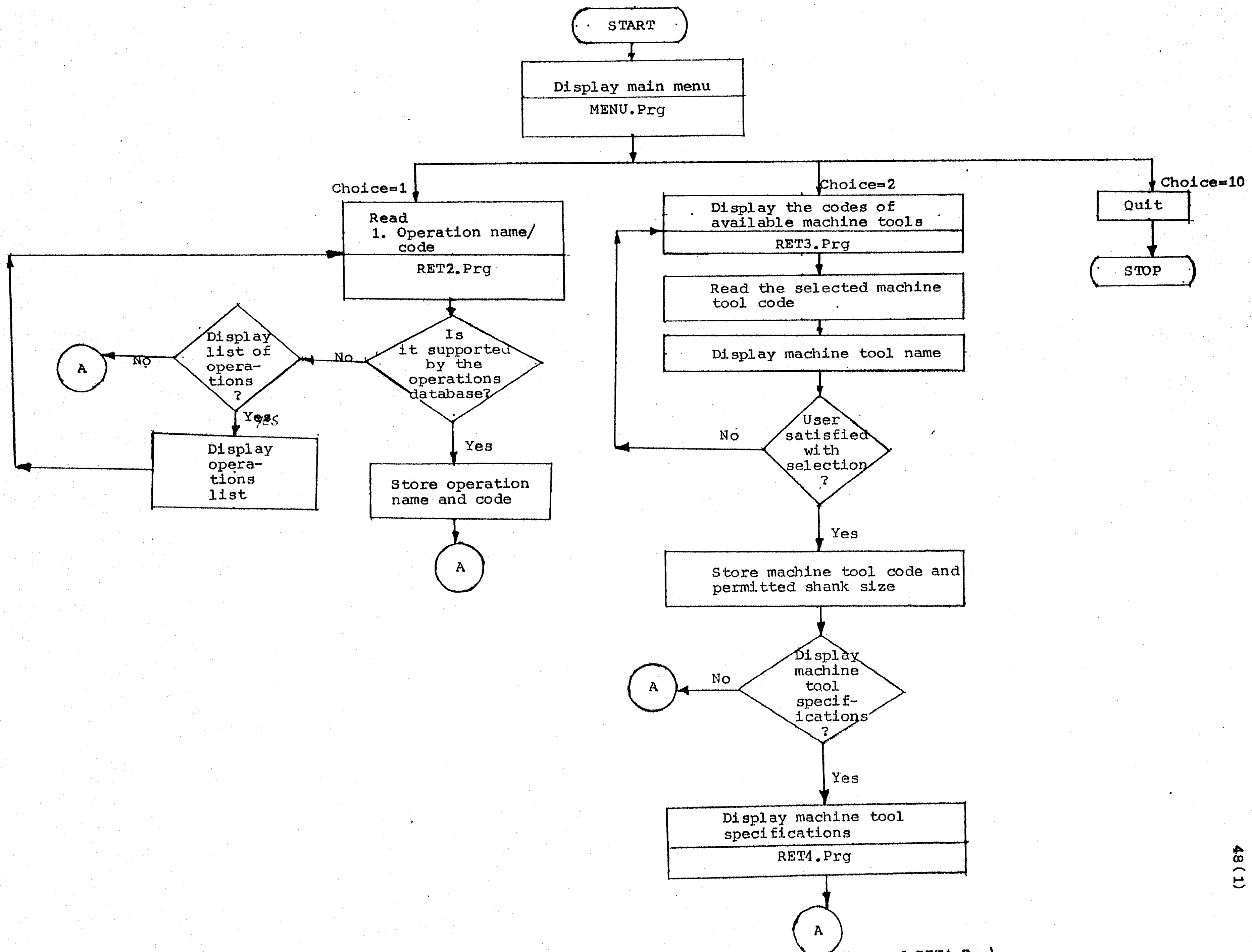


Fig. 4.5 Operation and machine tool selection (RET2.Prg, RET3.Prg and RET4.Prg). (contd...)

A

Choice	S. No.	Main Menu Sub-modules (MENU.Prg)	Program(s)
1	a	Selection of operation	RET2.Prg
2	b	Primary selection of suitable machine tool	RET3.Prg and RET4.Prg
3	c	Selection of work material	RET5.Prg
4	d	Selection of toolholder	TOLRET.Prg
5	e	Selection of insert	INSERT.Prg
6	f	Check for suitability of machine tool for the work piece	WP-ACO.Prg
7	g	Selection of cutting conditions	CUT-COND.Prg
8	h	Validation of cutting parameters on the machine tool	CHECK.Prg
9	i	Identifying the turret position and generation of process plan	MAGAZINE.Prg
10	j	Quit	-

EXIT

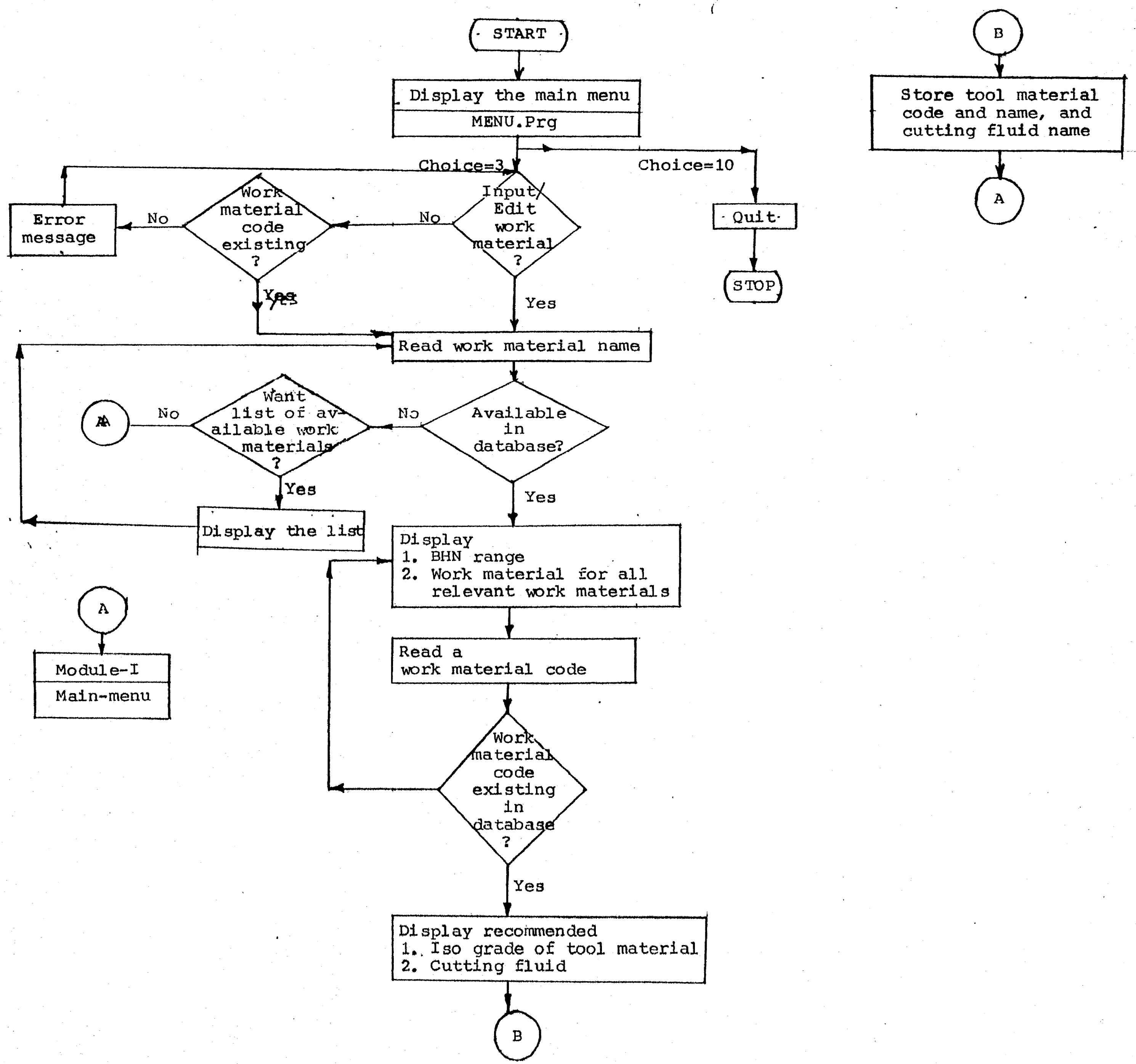


Fig. 4.6 Work material/tool material/cutting fluid selection (RET5.Prg).

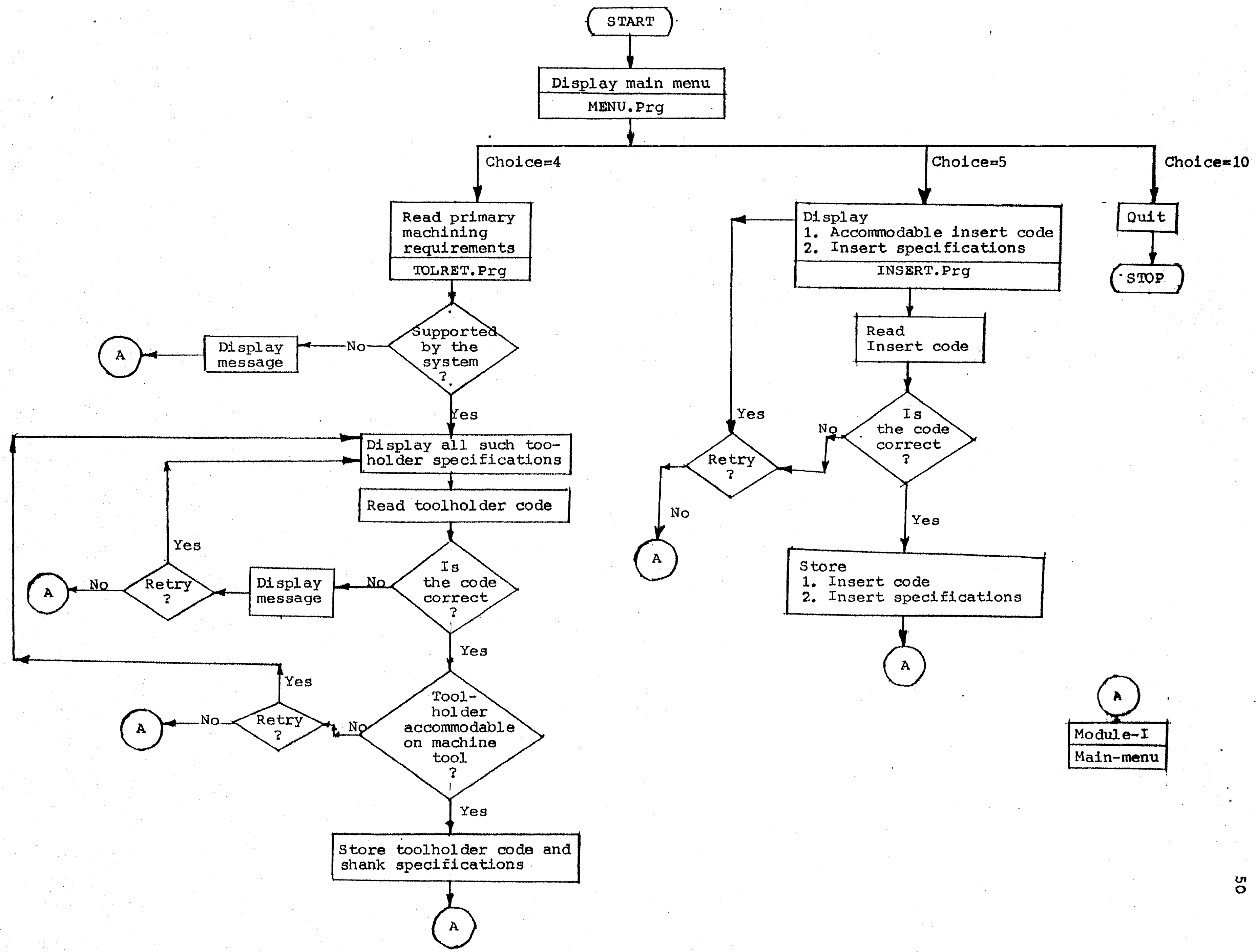


Fig. 4.7 Toolholder and insert selection (TOLRET.Prg and INSERT.Prg).

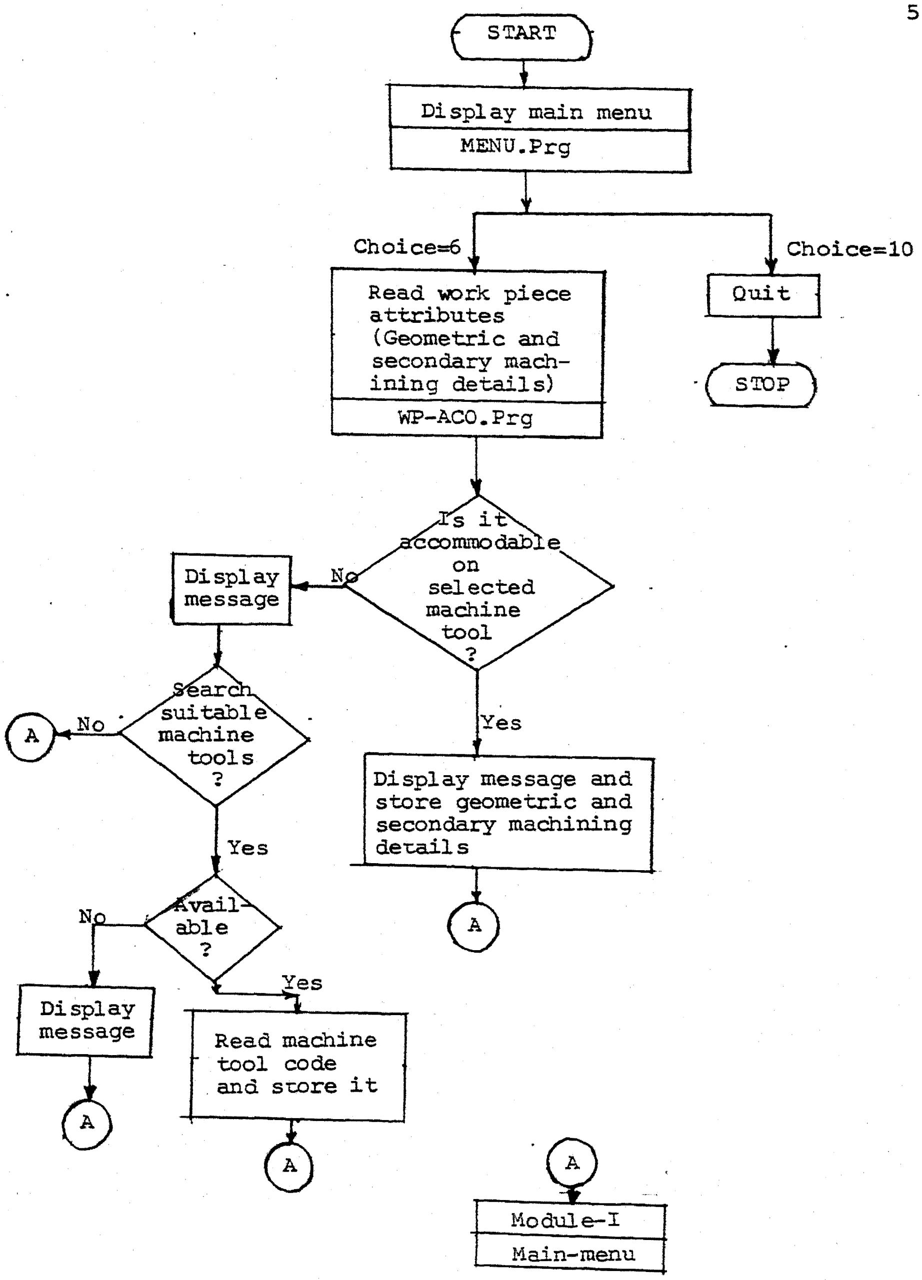


Fig. 4.8 Check for work piece accommodation (WP-ACO.Prg).

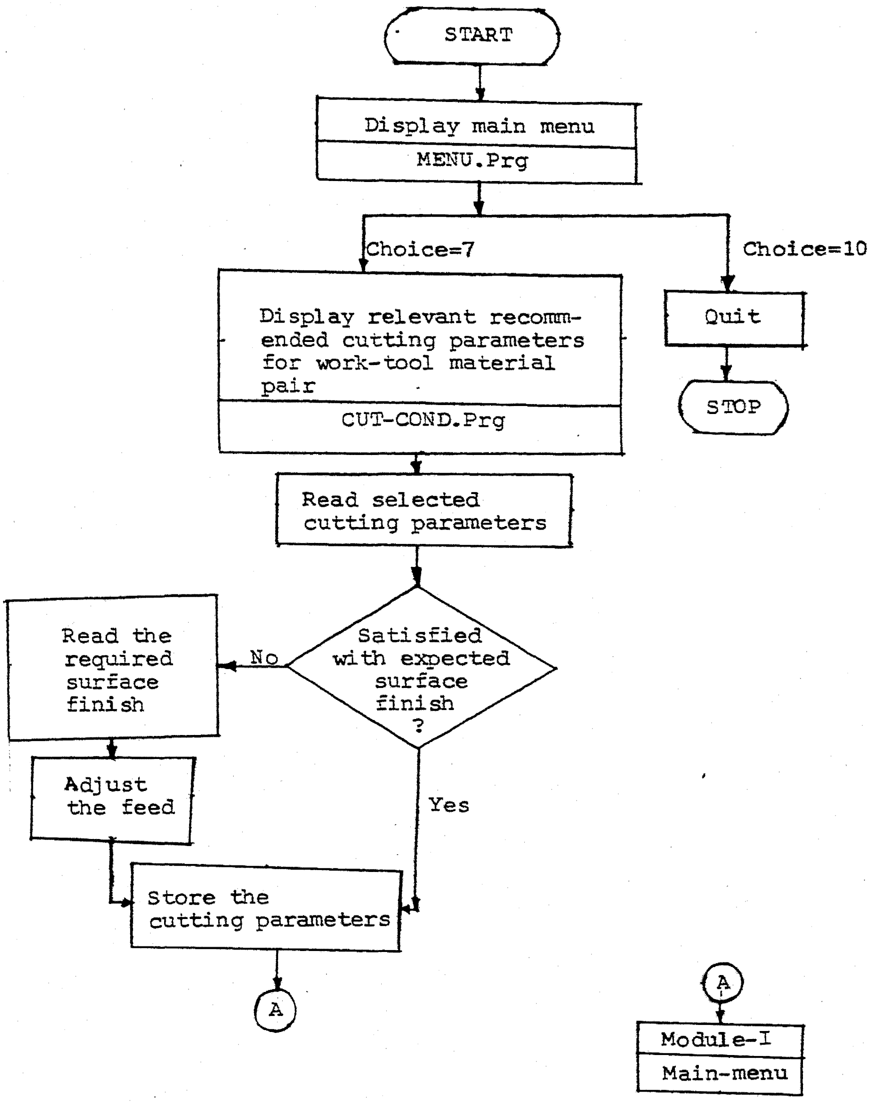
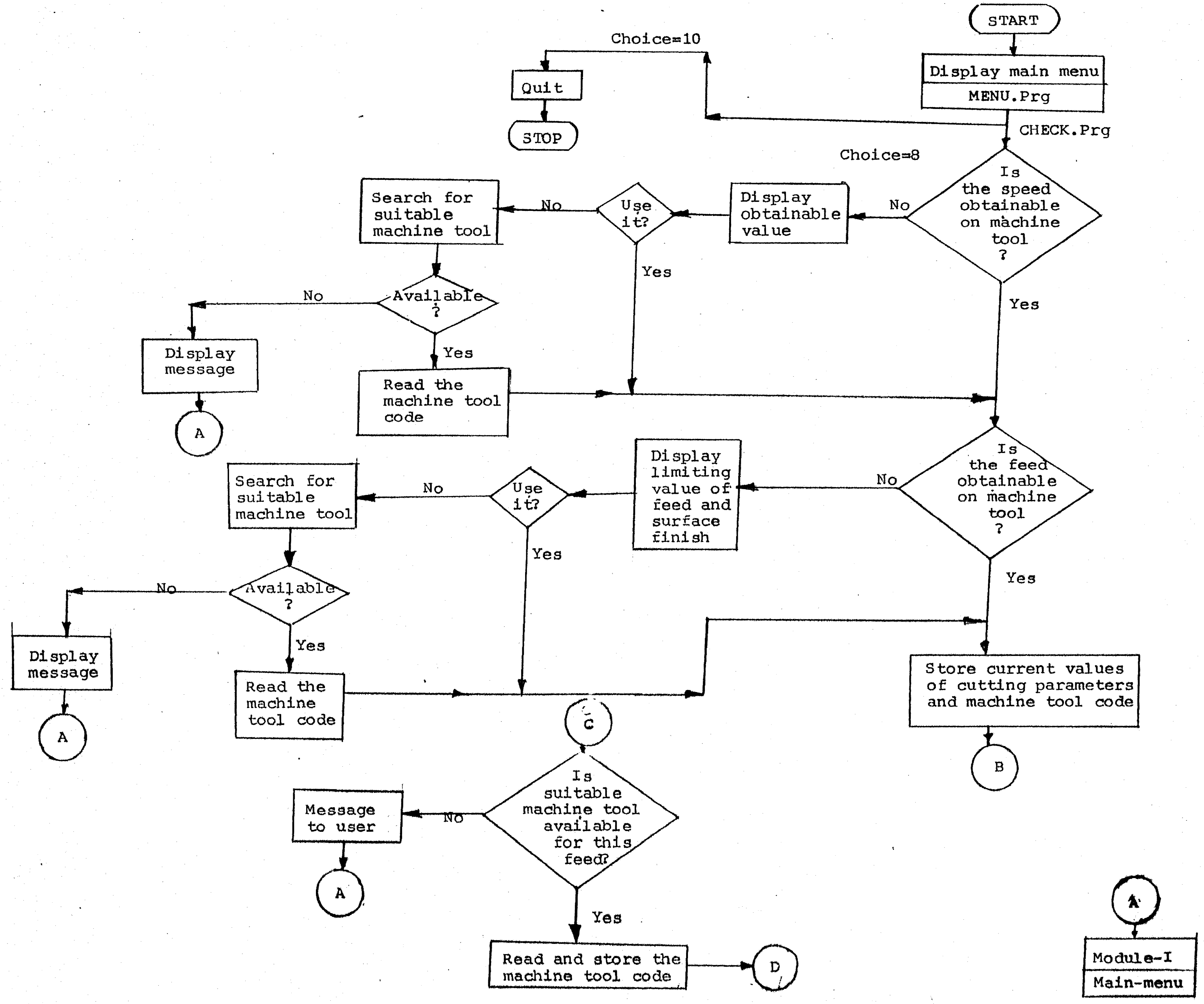


Fig. 4.9 Recommendations and input of cutting parameters (CUT-COND.Prg).


START
Display main menu
MENU.Prg
CHECK.Prg
Choice=10
Quit
STOP
Choice=8
Is the speed obtainable on machine tool ?
No
Display obtainable value
Use it?
No
Search for suitable machine tool
Available ?
No
Display message
A
Yes
Read the machine tool code
Yes
Yes
Is the feed obtainable on machine tool ?
No
Display limiting value of feed and surface finish
Use it?
No
Search for suitable machine tool
Available ?
No
Display message
A
Yes
Read the machine tool code
Yes
Yes
Store current values of cutting parameters and machine tool code
B
C
Is suitable machine tool available for this feed?
No
Message to user
A
Yes
Read and store the machine tool code
D
A
Module-I
Main-menu

contd

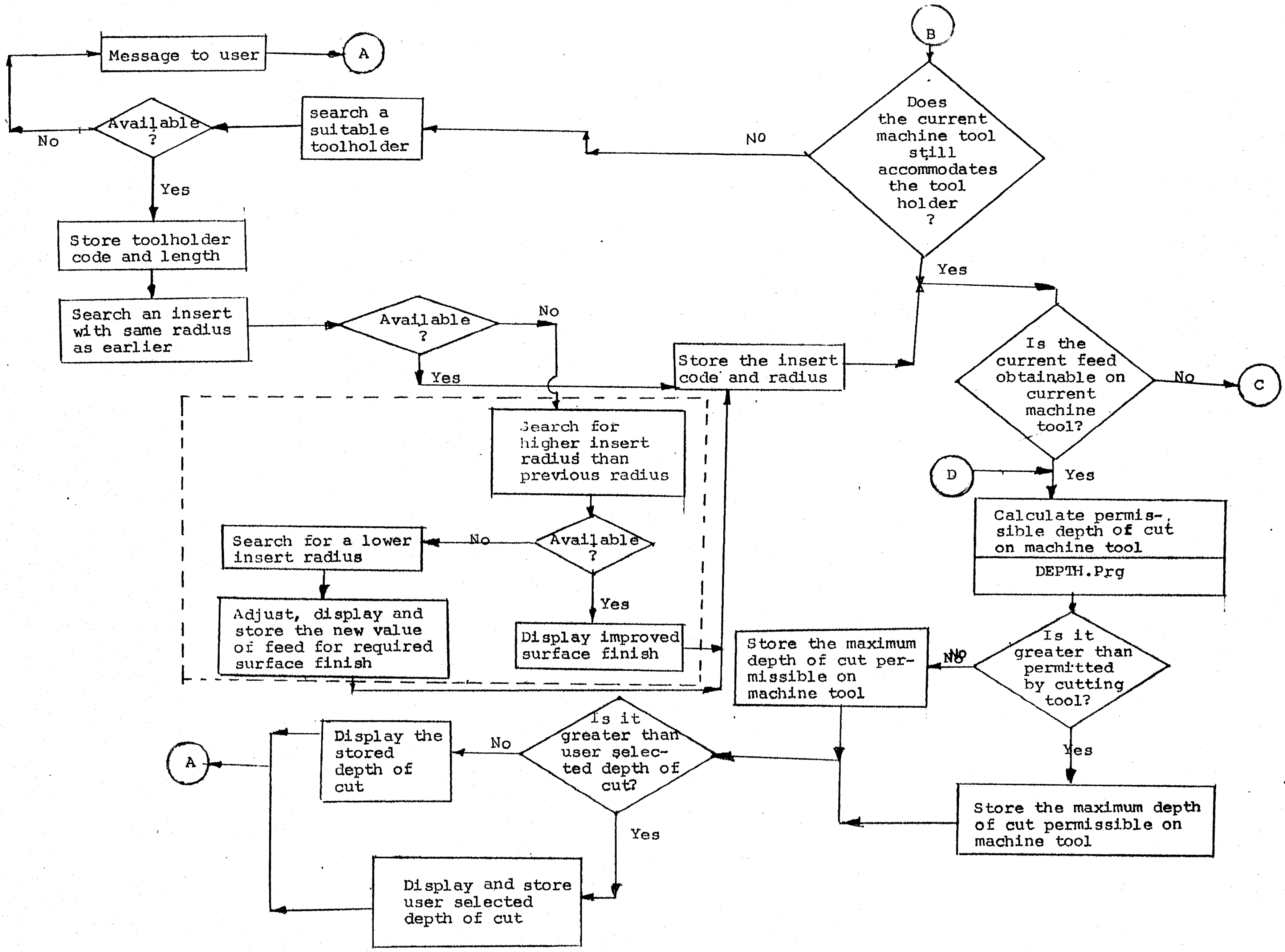


Fig. 4.10 Checking of cutting parameters with machine tool (CHECK.Prg).

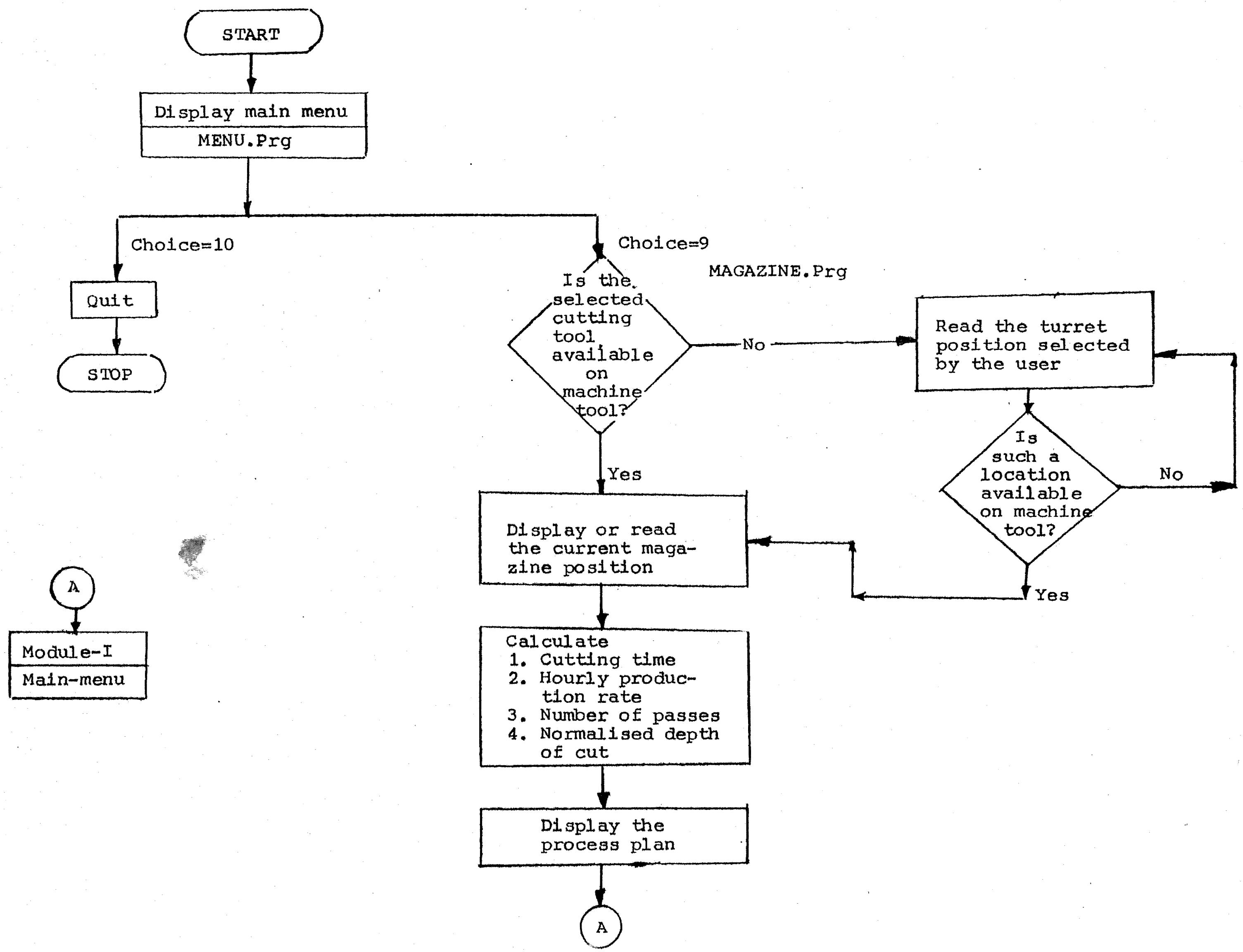


Fig. 4.11 Turret location and process plan generation (MAGAZINE.Prg).

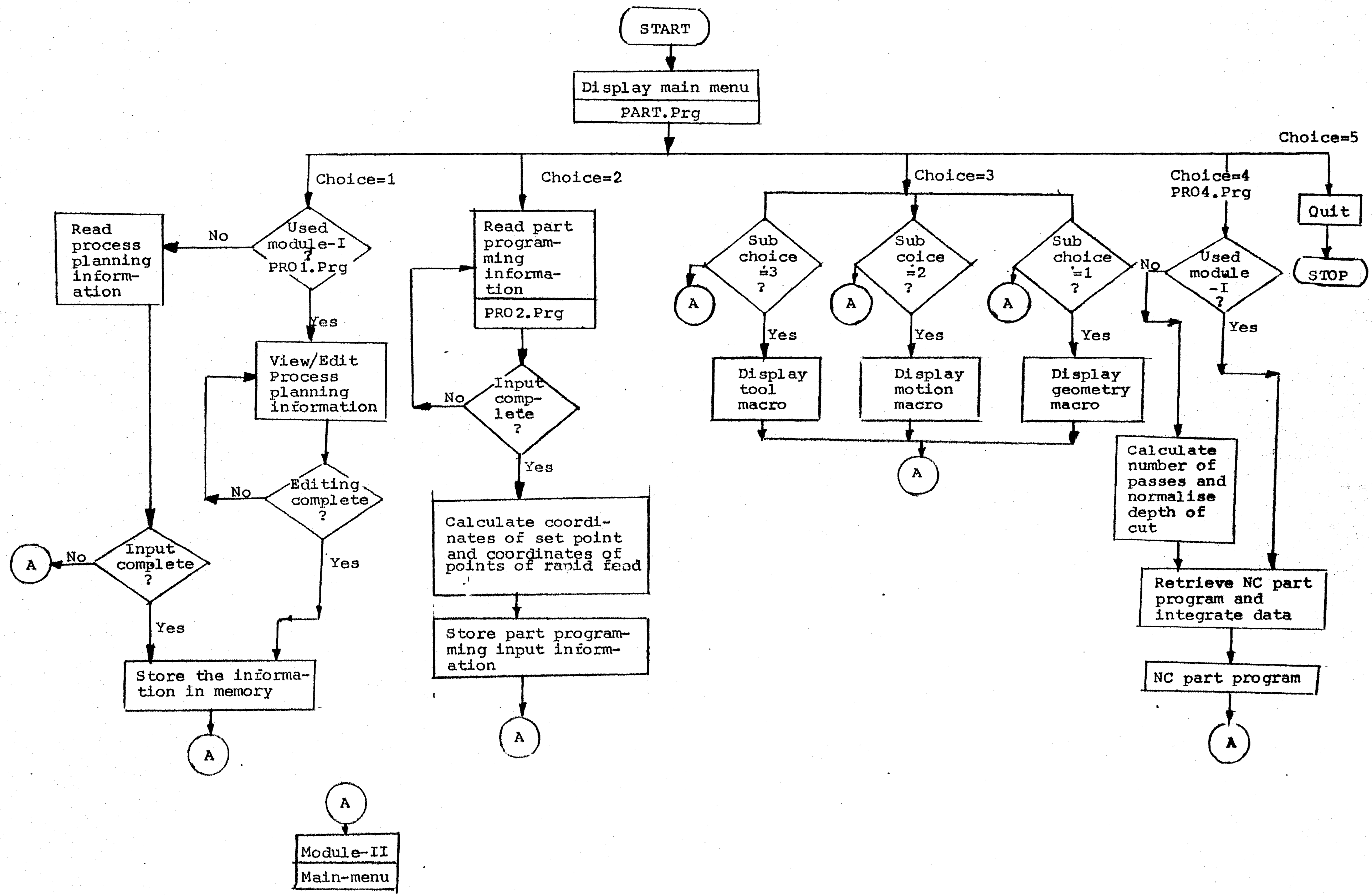


Fig. 4.12 Inputting/accepting information, retrieval of part program and macros.

A

Choice	S. No.	Module-II (Main menu (PART.Prg)	Program(s)
1	a	View/edit or input process planning information	PRO1.Prg
2	b	Input part programming information	PRO2.Prg
3	c	Retrieval of macros	PRO3.Prg
4	d	Generation of part program	PRO4.Prg
5	e	Quit	-

EXIT

improve upon the previous selection. The above program operates on a corresponding toolholder database (Figure 4.7).

(e) <u>Selection of Insert (INSERT.Prg)</u>: A list of available insert codes with relevant attributes is displayed for a pre-selected toolholder from the corresponding insert database. The program receives an insert code depending upon the user choice. The program also displays messages to aid the user for selecting a suitable insert.

A wrong insert code is detected by the program and helps to correct the user entry if required (Figure 4.7).

(f) <u>Check for Suitability of a Machine Tool for the Workpiece (WP-ACO.Prg)</u>: This program receives the workpiece attributes (geometric and secondary machining details i.e. total length to be machined, total depth to be removed, maximum diameter encountered in machining etc.) depending upon a preselected operation. It checks for the accommodability of the workpiece on the machine tool. In case the workpiece is not accommodable on the selected machine tool, then a suitable message is flashed. In such a situation, if the user wants the program also searches for a suitable machine tool from the machine tool database. The program then receives the code of the machine tool suitable for the workpiece (i.e. the machine tool is changed for all further considerations) (Figure 4.8).

(g) Selection of Cutting Conditions (CUT-COND.Prg): This program displays a set of cutting parameters (i.e. feed, speed and depth of cut) depending upon the operation and the combination of work-tool material pair. The data is retrieved from a corresponding machinability database. The user can input a set of cutting parameters selected by him. For general turning operations the program also calculates expected value of surface finish in terms of maximum peak to vally height and Hcla value.

If the user is not satisfied with the expected surface finish, then the required surface finish value in terms of maximum peak to valley height can be inputted and the program adjusts the feed suitably (Figure 4.9).

(h) Validation of Cutting Parameters on the Machine Tool (CHECK.Prg): This program checks the user selected value of feed and speed with the corresponding range available on the machine tool. The depth of cut is verified by a separate program(DEPTH.Prg).

If either of the values of speed and feed is falling below or exceeding the permissible values, then the program displays the limiting value of speed or the expected surface finish in case of general turning operations from the limiting value of feed or the value of feed itself in case of category B of operations. If the user is interested in this value then it is stored for further requirements, else the machine tool database is searched for the user selected value of these parameters. If such a machine tool(s) is available, the user

inputs the machine tool code for further use, otherwise the control is transferred to the main menu.

When a new machine tool is selected, the toolholder accommodability is again checked with the machine tool. If the toolholder is now not accommodable, then a suitable one is selected from corresponding toolholder database. The insert is also now checked for compatibility with toolholder. If the insert is not compatible, then a suitable insert with equal, higher or lower radius, is selected in the same order of preference, while the surface finish is maintained by altering value of feed for lower radius and for higher radius, the surface finish improves for the same feed. If the value of feed is required to be altered for a lower value of selected insert radius, then it is again verified, with the machine tool. If the value of feed is not obtainable on currently selected machine tool, then a suitable machine tool is again searched from machine tool database. If the search fails, the user is advised to quit, otherwise the user has to input the new machine tool code.

For checking the depth of cut, the program calculates the permissible depth of cut on the machine tool, retrieves a maximum depth of cut value permitted by the toolholder from corresponding toolholder database. These two values are compared with the user selected value of depth of cut. The lowest of the three values is then taken up by the system and displayed to the user. For threading operation corresponding

insert database is searched, while for drilling operation, toolholder database is not required to be searched (Figure 4.10).

The formulae used for calculating permissible depth of cut on machine tool [6], and the procedure for calculation is discussed in Appendix-C of this thesis.

(i) Identifying the Cutting Tool Location on Turret and Generation of Process Plan (MAGAZINE.Prg): This program operates on the internal turret position database or external turret position database depending upon whether the operation requires an internal or external toolholder. The program checks for the cutting tool availability on the machine tool turret. If it is available, then the turret position is displayed and stored, otherwise the user input is treated as the current turret position and corresponding database is updated by the program. Lastly program calculates the number of passes required to machine a given depth of material to be removed if the operation falls on category A or if it is a threading operation. The current depth of cut is then normalised, so that equal amount of material is removed in each pass. Also the machining time and hourly production rate is calculated. Depending upon the user choice the process plan is displayed in a tabular form. The flow chart for this program is shown in Figure 4.11.

4.2.2 Module-II:

This module has the submodules and application programs shown in Figure 4.12 and the sample outputs are given in Appendix-D of the thesis.

Main Menu (PART.Prg):

This program displays the main menu submodules a to e listed in Figure 4.12, and also it receives a choice from 1 to 5 to execute various functions of module-II.

(a) View/Edit or Input Process Planning Information (PRO1.Prg): This program allows the user to edit the process planning information from module-I if it has been used, otherwise the user has to input all the relevant process planning information here.

(b) Input Part Programming Information (PRO2.Prg): This program receives the part programming information like part program label, desirability of coolent during the operation, coordinates of starting point etc. If the user has not used module-I, then the information like total length to be machined and total depth of material to be removed during the operation is also to be inputted for general turning and threading operation.

The coordinates of end point, set point and points of rapid feed are calculated relative to the starting point. These entities are then stored into memory.

(c) Retrieval of Macros (PRO3.Prg): Motion, geometry, and tool and cutting condition macros for an operation can be displayed by using sub-menu choices from 1 to 3. These macros are retrieved from part program database.

(d) Generation of Part Program (PRO4.Prg): If the user has not used module-I then this program calculates the number of passes and normalises the depth of cut so that equal amount of

material is removed in each pass. The program retrieves the corresponding part program from database tags the data and displays processable part program.

4.2.3 Appending/Editing Database Files:

If a new machine tool is added on the shop floor, or a new work material is to be used or a new tool material or cutting fluid is to be used to machine an existing work material, or a new toolholder or insert is to be included in corresponding databases, then this module helps the user to store these new information in relevant databases. The sub-modules and application program flow charts of this module are shown in Figure 4.3.

Main Menu (NEW.Prg):

This program displays the menu options listed from a to g and it also receives a choice from 1 to 7 to execute the sub-modules.

(a) Appending for New Machine Tool (MCTOL-Prg): This program receives the specifications and code of the new machine tool and appends the machine tool databases.

(b) Appending for New Work Material (WORK.Prg): This program receives the new work material name, code, BHN range etc. and appends work material, tool material, all machinability databases, and cutting fluid databases.

(c) Editing for New Tool Material for Machining Existing Work Material (TOLMAT.Prg): This program receives a new tool material ISO grade, code of work material to be machined and the operation

name for which the new cutting fluid is to be used. Then it edits the tool material database and corresponding machinability database.

(d) Editing for New Cutting Fluid for Machining Existing Work Material (FLUID.Prg): This program receives a new cutting fluid name, the code of the work material to be machined and the operation name for which it is to be used. Then it edits the corresponding cutting fluid databases.

(e) Appending for New Toolholder (HOLDER.Prg): This program receives an operation name, toolholder code and attributes, and corresponding insert code and attributes. It then appends the corresponding toolholder and insert databases.

(f) Appending for New Insert (INS.Prg): This program receives the operation name, insert code, insert attributes and corresponding toolholder code. It then appends the insert database. The program is used if a new insert for an old toolholder is encountered.

4.2.4 Deleting Records from Databases (DELETE.Prg):

This program is used to delete database records (Figure 4.4) if a machine tool is no longer to be used on shop floor, a work material not being used any more, a toolholder or insert is not to be used any further. The program operates in following ways:

(a) Deletes a machine tool record for a given machine tool code from machine tool database.

(b) Deletes work material record for a given work material code from work material database and corresponding records from tool material database (for roughing and finishing), all machinability and cutting fluid databases.

(c) Deletes a toolholder record for a given toolholder code and operation name from relevant toolholder and insert databases.

(d) Deletes an insert record for a given insert code and operation name from relevant insert database.

CHAPTER - V

CONCLUSIONS

5.1 Conclusions:

An integrated system for process planning and NC-part program generation is developed for rotational components. The system generates process plan and part program for an operation supplied by the user. It supports seven operations namely turning, taper turning, facing, axial boring, axial boring shoulder, thread turning and axial drilling. The operations like turning, taper turning, facing and thread turning are divided into roughing and finishing categories.

For generating process planning information (module-I) like operation, machine tool, cutting tool (toolholder and insert), work material, tool material cutting fluid, cutting conditions and turret position of cutting tool, various databases were developed. Calculation of cutting time, hourly production rate and expected surface finish value, along with number of passes for a given depth to be removed and normalization of depth of cut is done by the programs.

Additional sub-modules are available for validation of cutting parameters and checking of work piece and toolholder accommodability on the selected machine tool.

Attempt has been made to make the system user friendly by providing adequate help facilities like providing support for

inputting operation name, toolholder and insert codes, work material name and code, and displaying parameters like shank size supported by the selected machine tool, available turret positions with the machine tool etc., at user selection levels where these parameters are critical. The system also flashes messages for incompatibilities encountered between various parameters and helps the user to select a suitable choice.

The NC-part programs and macros are stored in a part program database. For generating part programs (module-II) the user has a choice to use/edit recommended information from module-I or the relevant information can be fed externally.

The programs calculate coordinates of set point, end point and points of rapid feed relative to the starting point of the operation. In the independent mode of operation calculation for number of passes and depth of cut for equal amount of material removal in each pass is also carried out.

The part programming information like label of part program, desirability of coolent, and coordinates of starting point are to be fed externally.

The relevant data are tagged with the part program from library and a processable part program is generated. Various macros (motion, geometry, and cutting tool and cutting conditions) called in the part programs can also be displayed as per the user's choice.

Such a system would reduce the burden of repeatative activities on the part of process planner and part programmer.

5.2 Scope for Future Study:

The present system supports operations for rotational components only. Operations for non-rotational components like slab milling, end milling, slot milling and T-slot milling can also be included in the future work. Categories of operations (roughing and finishing) can be further subdivided into semi-rough and semi-finish ones to support more practical situations.

Some of the process planning functions like sequencing of operations, information about work holding devices, determination of production costs and editing of the process sheet can be included in module-I.

The part program library (module-II) can be enriched further by including more part programs which support operations for non-rotational components.

REFERENCES

1. Boothroyd, G., Fundamentals of Machining and Machine Tools, McGraw Hill, JAPAN, 1983.

2. Childs, J.J., Numerical Control Part Programming, Industrial Press Inc., USA, 1973.

3. Date, C.J., An Introduction to Database Systems, Vol. 1, Narosa Publishing House, INDIA, 1987.

4. Davies, B.J., Application of Expert Systems in Process Planning, Annals of the CIRP, Vol. 35, No. 2, 1986, pp. 451-452.

5. Eversheim, W., Holtz, B. and Zons, K.H., Application of Automatic Process Planning and NC Programming, Proc. of AUTOFACT WEST Society of Manufacturing Engineers, Anaheim, Calif., Nov. 1980(b), pp. 779-800.

6. Ghosh, A. and Mallik, A.K., Manufacturing Science, Affiliated East-West Press Pvt. Ltd., INDIA, 1985.

7. Grover, M.P. and Zimmers, Jr. E.W., CAD/CAM, Prentice Hall of India, 1985.

8. Haan, R.A., Group Technology Coding and Classification Applied to NC Part Programming, 14th Numerical Control Society, Annual Meeting and Technical Conference, Pittsburgh, Pa, March, 1977, pp. 403-418.

9. H.M.T. Ltd., Computer Numerical Control Technology Applications Machines, Marketing Division, HMT Ltd., Bangalore 560001, INDIA, December, 1986.

10. I.I.T. Research Institute, APT PART PROGRAMMING, McGraw Hill, USA, 1967.

11. Kerry, T.M., Integrating NC Programming with Machining and Group Technology, Proc. of 12th Numerical Control Society Annual Meeting and Technical Conference, 1975, pp. 149-162.

12. Kundra, T.K., Rao, P.N. and Tewari, N.K., Numerical Control and Computer Aided Manufacturing, Tata McGraw Hill, INDIA, 1985.

13. Prasad, R., Private Correspondence, Sandvik Asia Ltd., Delhi, INDIA.

14. Pressman, R.S. and Williams, J.E., Numerical Control and Computer-Aided Manufacturing, John Wiley and Sons, USA, 1976.

15. Ravichandran, C. and Raman, R.A., Design and Development of an Automatic Processing Software, 12th AIMTDR Conference IIT Delhi, 1986, pp. 137-141.

16. Ravichandran, C. and Sudheendra, G., Design and Development of a Machining Data Software Package for NC Lathe Users, Proc. of 11th AIMTDR Conference, IIT Madras, 1984, pp. 472-481.

17. SANDVIK (Coromant), T-MAX P Toolholders and Inserts, Sandvik Asia Ltd., Poona, Sept., 1987, INDIA.

18. SANDVIK (Coromant), T-MAX S Toolholders, Sandvik Asia Ltd., Poona, November, 1984, INDIA.

19. WIDIA, WIDAX TOOLS for External and Internal Machining, Widia India Ltd., Bangalore 560073, 1986, INDIA.

20. Simpson, A., Understanding DBASE-III Plus, BPB Publications, Delhi, 1986, INDIA.

APPENDIX - A

DBASE-III PLUS FEATURES

As discussed in Chapter-IV, the DBMS selected for the system implementation is DBASE-III plus. The reasons for selecting this DBMS are listed below:

- DBASE-III plus permits easy handling of databases, i.e. editing, deleting and appending of records is simple, which is well suited for the modules developed for updating records.
- Large number of databases are used in module-I. To create the structure of these databases, DBASE-III plus provides a simple procedure since the structure and application programs are independent of each other.
- Screen formatting is required for the development of menus and display of various entities in both the modules and the above mentioned DBMS meets well with this requirement.
- The developed system was to be made user friendly and the application programs of DBASE-III plus can easily handle this requirement.
- Frequent and fast searching of databases is needed in interactive systems and this is possible in the selected DBMS.

APPENDIX - B

STRUCTURE OF DATABASES

The structure of all the databases used in this study have been attached in this appendix.

```
Structure for database: A:OPN_DIR.dbf
Number of data records:        11
Date of last update   : 05/23/88
Field  Field Name   Type         Width    Dec
    1  OPN_NAME     Character       25
    2  OPN_CODE     Character        7
** Total **                         33

Structure for database: A:WM_DIR.dbf
Number of data records:        20
Date of last update   : 01/01/80
Field  Field Name   Type         Width    Dec
    1  WM_NAME      Character      100
    2  BHN_RANGE    Character        7
    3  WM_CODE      Character        3
** Total **                        111

Structure for database: A:TM_DIR.dbf
Number of data records:        40
Date of last update   : 02/20/88
Field  Field Name   Type         Width    Dec
    1  CODE         Character        1
    2  WM_CODE      Character        4
    3  ISO_AGRADE   Character        8
** Total **                         14

Structure for database: A:CUTF_129.dbf
Number of data records:        20
Date of last update   : 03/03/03
Field  Field Name   Type         Width    Dec
    1  WM_CODE      Character        3
    2  CUT_FLUID    Character      100
** Total **                        104
```

Structure for database: A:CUTF_3.dbf
Number of data records: 20
Date of last update : 03/03/03

Field	Field Name	Type	Width	Dec
1	WM_CODE	Character	3	
2	CUT_FLUID	Character	100	
** Total **			104	

Structure for database: A:MCDATA_1.dbf
Number of data records: 40
Date of last update : 01/01/80

Field	Field Name	Type	Width	Dec
1	WM_CODE	Character	3	
2	TM_CODE	Character	7	
3	FEED1	Numeric	4	2
4	FEED2	Numeric	4	2
5	FEED3	Numeric	4	2
6	SPEED1	Numeric	4	
7	SPEED2	Numeric	4	
8	SPEED3	Numeric	4	
9	DCUT_RAN	Character	9	
** Total **			44	

Structure for database: A:MCDATA_3.dbf
Number of data records: 20
Date of last update : 02/18/88

Field	Field Name	Type	Width	Dec
1	WM_CODE	Character	3	
2	TM_CODE	Character	7	
3	FEED1	Numeric	4	2
4	FEED2	Numeric	4	2
5	FEED3	Numeric	4	2
6	FEED4	Numeric	4	2
7	SPEED	Numeric	3	
** Total **			30	

Structure for database: A:MCDATA_9.dbf
Number of data records: 40
Date of last update : 03/03/03

Field	Field Name	Type	Width	Dec
1	WM_CODE	Character	3	
2	TM_CODE	Character	7	
3	SPEED1	Numeric	3	
4	SPEED2	Numeric	3	
** Total **			17	

Structure for database: A:EXMG_POS.dbf
Number of data records: 34
Date of last update : 05/23/88

Field	Field Name	Type	Width	Dec
1	MCT_CODE	Character	3	
2	MAG_POS	Character	2	
3	TLH_CODE	Character	7	
4	INS_CODE	Character	5	
5	TM_CODE	Character	7	
** Total **			25	

Structure for database: A:INMG_POS.dbf
Number of data records: 34
Date of last update : 05/19/88

Field	Field Name	Type	Width	Dec
1	MCT_CODE	Character	3	
2	TLH_CODE	Character	7	
3	INS_CODE	Character	5	
4	TM_CODE	Character	7	
5	MAG_POS	Character	2	
** Total **			25	

Structure for database: A:FORC_DIR.dbf
Number of data records: 20
Date of last update : 03/03/03

Field	Field Name	Type	Width	Dec
1	WM_CODE	Character	3	
2	UO	Numeric	4	2
** Total **			8	

Structure for database: A:MCT_DIR.dbf
Number of data records: 11
Date of last update : 03/19/88

Field	Field Name	Type	Width	Dec
1	MCT_NAME	Character	70	
2	MCT_CODE	Character	5	
** Total **			76	

```
Structure for database: A:TRN_SPE.dbf
Number of data records:       5
Date of last update   : 03/19/88
Field  Field Name  Type       Width    Dec
    1  MCT_CODE    Character      3
    2  CTC_DIST    Numeric        5
    3  SWG_BED     Numeric        5
    4  SWG_CRG     Numeric        6
    5  MXTERLEN    Numeric        6
    6  MIN_SPEED   Numeric        6
    7  MAX_SPEED   Numeric        6
    8  LNR_FED     Numeric        6
    9  MINLNC_FED  Numeric        6
   10  MAXLNC_FED  Numeric        6
   11  CRR_FED     Numeric        6
   12  MINCRC_FED  Numeric        6
   13  MAXCRC_FED  Numeric        6
   14  INT_TOOLS   Character      2
   15  EXT_TOOLS   Character      2
   16  MAXTRTOLSZ  Numeric        3
Press any key to continue...
   17  MAXBARSZ    Numeric        3
   18  SPNDL_PWR   Numeric        6      3
   19  POS_ACCRY   Numeric        6      3
   20  BED_TYPE    Character     30
** Total **                     126

Structure for database: A:TLHGEO_1.dbf
Number of data records:      56
Date of last update   : 03/15/88
Field  Field Name  Type       Width    Dec
    1  TLH_CODE    Character      7
    2  LENGTH      Numeric        3
    3  HEIGHT      Numeric        2
    4  WIDTH       Numeric        2
    5  A_ANGL      Numeric        3
    6  SIN_PHI     Numeric        5      3
    7  B_RAKE      Numeric        2
    8  S_RAKE      Numeric        2
    9  F_CLR       Numeric        2
   10  S_CLR       Numeric        2
   11  E_CUTE      Numeric        2
   12  S_CUTE      Numeric        2
   13  MAX_CLEN    Numeric        4      1
** Total **                      39
```

Structure for database: A:TLHGEO_2.dbf
Number of data records: 14
Date of last update : 03/16/88

Field	Field Name	Type	Width	Dec
1	TLH_CODE	Character	7	
2	LENGTH	Numeric	3	
3	HEIGHT	Numeric	2	
4	DIAMETER	Numeric	2	
5	MIN_DIA	Numeric	2	
6	A_ANGL	Numeric	3	
7	SIN_PHI	Numeric	5	3
8	B_RAKE	Numeric	3	
9	S_RAKE	Numeric	2	
10	F_CLR	Numeric	2	
11	S_CLR	Numeric	2	
12	E_CUTE	Numeric	2	
13	S_CUTE	Numeric	2	
14	MAX_CLEN	Numeric	4	1
** Total **			42	

Structure for database: A:TLHGEO_3.dbf
Number of data records: 8
Date of last update : 01/01/80

Field	Field Name	Type	Width	Dec
1	TLH_CODE	Character	5	
2	DIAMETER	Numeric	4	
3	LENGTH	Numeric	4	
4	NO_INSERTS	Numeric	4	
5	SHANK_DIA	Numeric	3	
6	SEMI_ANGL	Numeric	3	
7	TLENGTH	Numeric	3	
8	SIN_PHI	Numeric	5	3
** Total **			32	

Structure for database: A:TLHGEO_9.dbf
Number of data records: 9
Date of last update : 12/19/87

Field	Field Name	Type	Width	Dec
1	TLH_CODE	Character	9	
2	HEIGHT	Numeric	6	2
3	WIDTH	Numeric	6	2
4	LENGTH	Numeric	6	2
5	MIN_PITCH	Numeric	6	2
6	MAX_PITCH	Numeric	6	2
7	MIN_TPI	Numeric	6	2
8	MAX_TPI	Numeric	6	2
9	MAX_MAJ_DI	Numeric	6	2
** Total **			58	

Structure for database: A:INSGEO_1.dbf
Number of data records: 174
Date of last update : 01/01/80

Field	Field Name	Type	Width	Dec
1	TLH_CODE	Character	7	
2	INS_CODE	Character	5	
3	LENGTH	Numeric	4	1
4	THICKNESS	Numeric	4	2
5	RADIOUS	Numeric	3	1
** Total **			24	

Structure for database: A:INSGEO_3.dbf
Number of data records: 8
Date of last update : 02/18/88

Field	Field Name	Type	Width	Dec
1	TLH_CODE	Character	5	
2	INS_CODE	Character	5	
3	L	Numeric	4	2
4	S	Numeric	4	2
5	R	Numeric	4	2
6	THETA	Numeric	2	
7	ALPHA	Numeric	2	
** Total **			27	

Structure for database: A:INSGEO_6.dbf
Number of data records: 27
Date of last update : 05/12/88

Field	Field Name	Type	Width	Dec
1	TLH_CODE	Character	4	
2	INS_CODE	Character	4	
3	THK	Numeric	4	2
4	RAD	Numeric	4	2
5	ANG	Numeric	2	
6	RDEP_CUT	Numeric	5	3
7	FDEP_CUT	Numeric	5	3
8	SIN_PHI	Numeric	5	3
** Total **			34	

Structure for database: A:PART.dbf
Number of data records: 7
Date of last update : 05/13/88

Field	Field Name	Type	Width	Dec
1	OPN_CODE	Character	7	
2	GEOMETRY	Memo	10	
3	MOTION	Memo	10	
4	CUT_TOOL	Memo	10	
5	PART_PRO	Memo	10	
6	PART_PRO1	Memo	10	
** Total **			58	

APPENDIX - C

FORMULAE USED

As discussed in Chapter-IV, the calculations for finding out the permissible depth of cut on a given machine tool (Program DEPTH.Prg), were carried out according to the following procedure:

The power consumption is given by

$$W = F_c v \tag{1}$$

The energy consumption per unit volume of material removal, commonly known as specific energy, is given by

$$U_c = \frac{F_c}{wt_1} \tag{2a}$$

$$W = U_c Q \tag{2b}$$

where Q is the volume rate of material removal. An examination of the various published data shows that U_c fits the power law

$$U_c = U_o [t_1]^{-0.4}$$

where the value of U_o depends on the material. Substituting U_c from equation (2a) in equation (1) we get

$$F_c = 1000 \times t_1 \times w \times U_o \times [t_1]^{-0.4} \text{ Newtons} \tag{3}$$

Now for general turning and threading operations:

$$t_1 = f \sin\phi \tag{4}$$

$$w = d/\sin\phi \tag{5}$$

for drilling operation:

$$t_1 = (f/2)\ \sin\beta \tag{6}$$

$$w = (D/2)/\sin\beta \tag{7}$$

Substituting the value of t_1 and w from equations (4), (5) and (6), (7) in (3) respectively we get:

For turning and threading operations:

$$d = \left(\frac{F_c}{1000 \times U_o}\right) \times (\sin\phi)^{0.4} \times (f)^{-0.6} \tag{8}$$

For drilling operation:

$$D = \left(\frac{F_c}{250 \times U_o}\right) \times \left(\frac{\sin\beta}{2}\right)^{0.4} (f)^{-0.6} \tag{9}$$

For calculating d and D the value of ϕ and β are the attributes of toolholder, U_o is stored in database for each material. The value of W comes from machine tool database and f and v are selected by the user hence

$$F_c = \frac{3W}{50v} \tag{10}$$

which can be substituted in equations (8) and (9) and $D = d_1 - d_2$ where d_1 and d_2 are final and pilot hole sizes respectively.

Formulae used for cutting time are:

Turning, taper turning and threading: $\frac{L}{fN}$
Axial boring and shoulder boring :

Facing : $\frac{d_m}{2fN}$

Axial drilling : $\frac{L}{fN}$

Surface finish:

The formulae used for determining the surface finish value for general turning operations are

$$h_{max} = \frac{f^2}{8R}$$

$$hcla = \frac{f^2}{18\sqrt{3}\,R}$$

APPENDIX - D

SAMPLE RESULTS

For the sample runs of module-I and module-II, the operations considered are:

(a) Turning Rough

(b) Thread Turning Finish

(c) Axial Drilling.

The external inputs given are:

(a) Turning Rough:

(i)	Operation name: TURNING ROUGH		
(ii)	Total length of the work piece	:	75.0 mm
(iii)	Maximum diameter of work piece	:	50.0 mm
(iv)	Work material	:	Carbon steel
(v)	Length of tool inside turret	:	25.0 mm
(vi)	Total depth to be removed	:	10.0 mm
(vii)	Maximum diameter encountered in machining: 50.0 mm		
(viii)	Length to be machined	:	50.0 mm
(ix)	Required dimensional accuracy	:	±0.02 mm
(x)	Coordinates of starting point	:	75.0, -25.0
(xi)	Coolent status	:	ON
(xii)	Part number	:	Turning Rough

(b) Thread Turning Finish:

(i)	Operation name: THREAD TURNING FINISH		
(ii)	Length of the work piece	:	60.0 mm
(iii)	Maximum diameter of work piece	:	40.0 mm

(iv) Length of tool inside turret : 25.0 mm

(v) Work material : Alloy steel

(vii) Total length to be machined : 25.0 mm

(viii) Nominal diameter encountered in machining : 18.0 mm

(ix) Pitch of the threads : 1 mm

(x) Required dimensional accuracy : ±0.025 mm

(xi) Coordinates of starting point : 40.0, -9.0

(xii) Coolent status : ON

(xiii) Part number : Thread Turning Finish

(c) Axial Drilling:

(i) Operation name: AXIAL DRILLING

(ii) Length of the work piece : 100 mm

(iii) Maximum diameter of work piece : 50.0 mm

(iv) Length of tool inside turret : 20.0 mm

(v) Work material : Cast iron

(vi) Total depth to be machined : 20.0 mm

(viii) Diameter of hole to be drilled : 22.0 mm

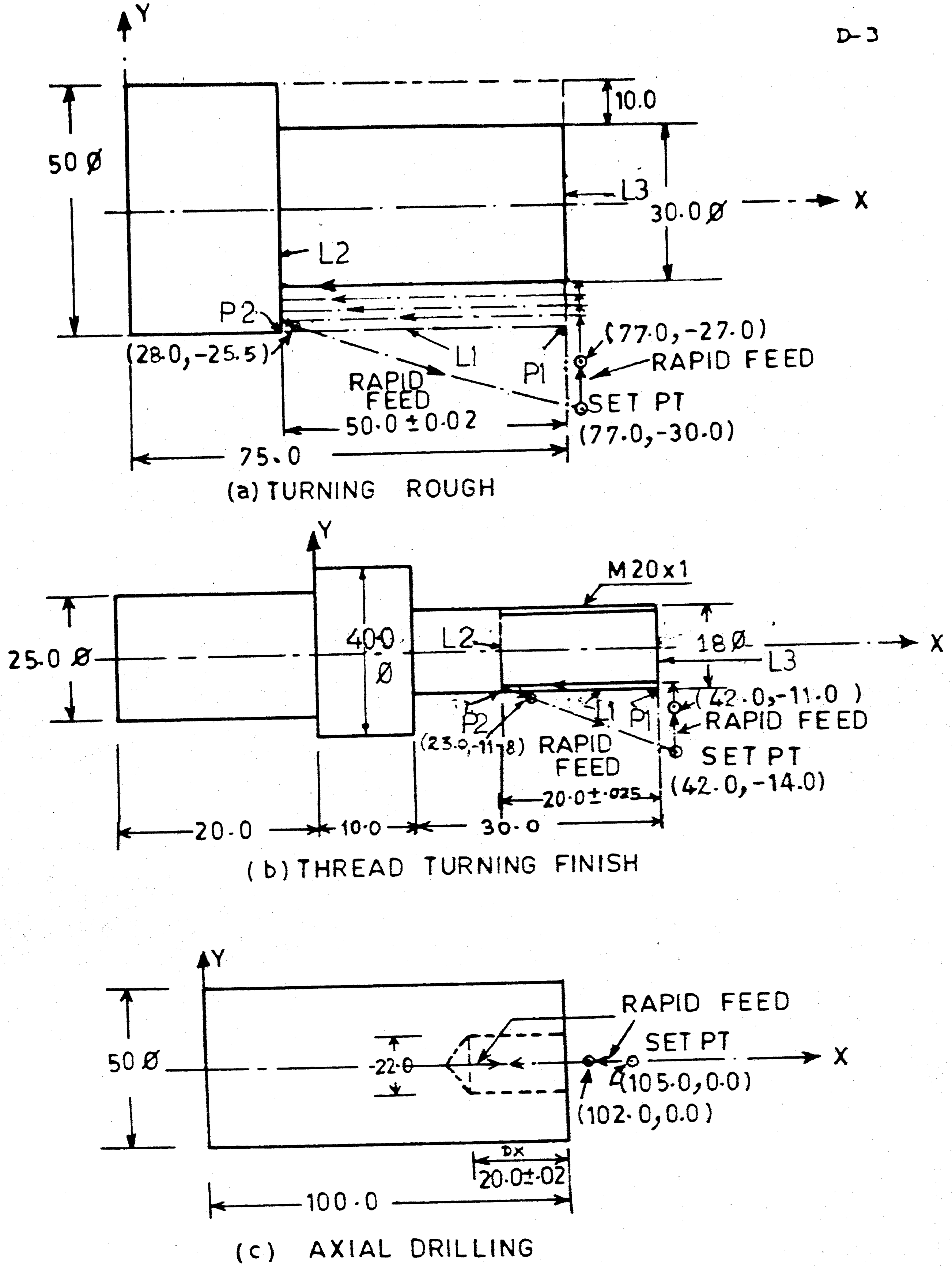
(viii) Diameter of pilot hole : 18.0 mm

(ix) Dimensional accuracy required : ±0.02 mm

(x) Coordinates of starting point : 100.0, 0.0

(xi) Part number : Axial Drilling

The process plans for these operations are given in Table D-1(a), (b) and (c), while the part programs and macros are given in Table D-2(a), (b) and (c). Part drawings and tool path are illustrated in Figure D-1(a), (b) and (c).



(a) TURNING ROUGH

(b) THREAD TURNING FINISH

(c) AXIAL DRILLING

ALL DIMENSIONS IN mm. (NOT TO SCALE)

Fig. D-1 PART DRAWINGS AND TOOL PATH.

PROCESS PLANNING INFORMATION

OPERATION	: TURNING ROUGH	MACHINING TIME :	34.9065999999999974 SEC.
MACHINE TOOL	: 212	COMPONENTS/HR :	103
TOOL HOLDER	: TT0691P	(BASED ON MACHINING TIME ONLY)	
INSERT	: T005P	NUMBER OF PASSES:	4
TOOL MATERIAL	: P20-P40		
FEED (m.m./min.)	: 343.770	EXPECTED SURFACE FINISH	
SPEED (rpm)	: 859.440	H max (m.m.) :	0.0500000
DEPTH OF CUT	: 2.500	HCLA :	0.0128360
TURRET POSITION	: 05		
CUTTING FLUID	:		

EXTREME PRESSURE SOLUBLE OIL OR SYNTHETIC FLUID

WORK MATERIAL : TOOL LIFE : 15 min.

NON ALLOY CARBON STEEL NORMALISED C=.7%

BHN RANGE : 180-250

FEED(MM/REV): 0.40 SPEED(M/MIN): 135.00

s any key to continue...

TABLE D-1(a)

(Contd...)

PROCESS PLANNING INFORMATION

OPERATION	: TURNING ROUGH	MACHINING TIME :	34.9065999999999974 SEC.
MACHINE TOOL	: 212	COMPONENTS/HR :	103
TOOL HOLDER	: TT0691P	(BASED ON MACHINING TIME ONLY)	
INSERT	: T006P	NUMBER OF PASSES:	4
TOOL MATERIAL	: P20-P40		
FEED (m.m./min.)	: 343.770	EXPECTED SURFACE FINISH	
SPEED (rpm)	: 859.440	H max (m.m.) :	0.0250000
DEPTH OF CUT	: 2.500	HCLA :	0.0064150
TURRET POSITION	: 04		
CUTTING FLUID	: EXTREME PRESSURE SOLUBLE OIL OR SYNTHETIC FLUID		
WORK MATERIAL	: NON ALLOY CARBON STEEL NORMALISED C=.7%	TOOL LIFE :	15 min.
BHN RANGE	: 180-250		
FEED(MM/REV):	0.40	SPEED(M/MIN):	135.00

ss any key to continue...

TABLE D-1(a)

(Contd...)

PROCESS PLANNING INFORMATION

OPERATION	: TURNING ROUGH	MACHINING TIME :	34.9065999999999974 SEC.
MACHINE TOOL	: 212	COMPONENTS/HR :	103
TOOL HOLDER	: TT0691P	(BASED ON MACHINING TIME ONLY)	
INSERT	: T007P	NUMBER OF PASSES:	4
TOOL MATERIAL	: P20-P40		
FEED (m.m./min.)	: 343.770	EXPECTED SURFACE FINISH	
SPEED (rpm)	: 859.440	H max (m.m.) :	0.0166666
DEPTH OF CUT	: 2.500	HCLA :	0.0042766
TURRET POSITION	: 03		
CUTTING FLUID	:		

EXTREME PRESSURE SOLUBLE OIL OR SYNTHETIC FLUID

WORK MATERIAL : TOOL LIFE : 15 min.

NON ALLOY CARBON STEEL NORMALISED C=.7%

BHN RANGE : 180-250

FEED(MM/REV): 0.40 SPEED(M/MIN): 135.00

ess any key to continue...

TABLE D-1(a)

(Contd...)

```
-----------------PROCESS PLANNING INFORMATION------------------

OPERATION         : THREAD TURNING FINISH  MACHINING TIME :
MACHINE TOOL      : 223                          1.590400000000     SEC.
TOOL HOLDER       : DH03                   COMPONENTS/HR  :  2263
INSERT            : D003             (BASED ON MACHINING TIME ONLY)
TOOL MATERIAL     : K15-K15                NUMBER OF PASSES:  3
PITCH IN m.m.     :   1.00
SPEED (rpm)       :  2829.420
DEPTH OF CUT      :  0.050
TURRET POSITION   : 06
CUTTING FLUID     :
 EXTREME PRESSURE SOLUBLE OIL OR SYNTHETIC FLUID

WORK MATERIAL    :
  ALLOY STEEL ANNEALED

BHN RANGE        : 125-200
ANGLE OF THREADS: 60 DEG.                SPEED(M/MIN.): 160.00
```

ess any key to continue...

TABLE D-1 (b)

PROCESS PLANNING INFORMATION

```
OPERATION            : AXIAL DRILLING          MACHINING TIME :
MACHINE TOOL         : 212                            3.317500000        SEC.
TOOL HOLDER          : HD05                    COMPONENTS/HR   :   1085
INSERT               : H002             (BASED ON MACHINING TIME ONLY)
TOOL MATERIAL        : K20-K20
FEED (m.m./min.)     :   361.720
SPEED (rpm)          :  1446.860
DRILL DIA. (m.m.):  22.000
TURRET POSITION      : 01
CUTTING FLUID        :
 NO CUTTING FLUID REQUIRED

WORK MATERIAL      :
  CAST IRONS HIGH TENSILE GREY

BHN RANGE          : 200-330
FEED(MM/REV): 0.25                         SPEED(M/MIN): 100.00
```

ess any key to continue...   TABLE D-1 (c)

TABLE D-2 (a, b, and c) SAMPLE PROCESS PLANS.

```
123456 8 10                                              72 73        80
PARTNO     TURNING ROUGH                            NO. OF PASSES :  4
         CLPRINT
         MACHIN/ 212
X        =    77.000
Y        =   -30.000
XS       =    75.0000
YS       =   -25.0000
XL       =    25.000
XDS      =     0.000
YDS      =     3.000
XD       =     3.000
YD       =    -3.000
DEPTH    =   10.000
DCUT     =   2.500
LEN      =  125.000
D        =   0.800
SPEED    =   859.440
FEED     =   343.770
COOL     =  ON
TOLID    =  05

Press any key to continue

123456 8 10                                                    7273 80
TOLNO    =  05
YC       = YS
CAL1)      LOOPST
           YS = YS + DCUT
           CALL/CYL,X = X, Y= Y,X1 = XS,Y1 = YS,X2 = XL
           CALL/TOOL,ID = TOLID,TN = TOLNO,DIA = D,$
           F = FEED,N = SPEED,A = COOL,L = LEN
           CALL/STL,XDS = XDS,YDS = YDS,XD = XD,YD = YD
           IF (ABSF(YS-YC) - DEPTH) CAL1, CAL2, CAL2
CAL2)      LOOPND
           SPNDL/OFF
           COOLNT/OFF
           FINI
```

```
123456 8 10                          72 73         80
CYL      = MACRO/X,Y,X1,Y1,X2
P1       = POINT/X1,Y1
P2       = POINT/X2,Y1
SETPT    = POINT/X,Y
L1       = LINE/P1,P2
L2       = LINE/P2,PERPTO,L1
L3       = LINE/P1,PERPTO,L1
           TERMAC

Press any key to continue...
```

```
123456 8 10                          72  73        80
TOOL     = MACRO/ID,L,TN,DIA,N,F,A
           TOOLNO/ID,LENGTH,L
           SELECTL/TN,LENGTH,L
           LOADTL/ID,TN
           CUTTER/DIA
           SPNDL/RPM,N,CCLW
           FEDRAT/MMPM,F
           COOLNT/A
           TERMAC

Press any key to continue...
```

```
123456 8 10                          72 73         80
STL      = MACRO/XDS,YDS,XD,YD
           FROM/SETPT
           RAPID
           GODLTA/XDS,YDS
           GO/TO,L1,TO,L3
           GOLFT/L1,TO,L2
           GODLTA/XD,YD
           RAPID
           GOTO/SETPT
           TERMAC

Press any key to continue...
```

Table D-2(a)

```
1234456 8 10                                7273    80
PARTNO     THREAD TURNING FINISH         NO. OF PASSES :  3
           CLPRINT
           MACHIN/223
X        =   42.000
Y        =  -14.000
XS       =   40.0000
YS       =   -9.0000
XL       =   15.000
XDS      =    0.000
YDS      =    3.000
XD       =    3.000
YD       =   -3.000
DEPTH    =   0.140
DCUT     =  0.050
LEN      = 100.000
D        =  0.300
SPEED    = 2829.420
PITCH    = 2829.420
COOL     = ON
TOLID    = 06

Press any key to continue

                                                  7273 80
123456 8 10
TOLNO   =  06
YC      = YS
CAL1)     LOOPST
          CALL/CYL,X = X,Y = Y,X1 = XS,Y1 = YS,X2 = XL
          CALL/TOOL,ID = TOLID,TN = TOLNO,DIA = D,$
          N = SPEED,COOL = A,L = LEN
          CALL/THR,XDS = XDS,YDS = YDS,XD = XD,$
          YD = YD,DCUT = DCUT,P = PITCH
          IF (ABSF(YS - YC) - DEPTH) CAL1,CAL2,CAL2
          YS = YS + DCUT
 CAL2)    LOOPND
          SPNDL/OFF
          COOLNT/OFF
          FINI
```

TABLE D-2 (b)

(Contd . . .)

```
123456 8 10                           7273    80
CYL     = MACRO/X,Y,X1,Y1,X2
P1      = POINT/X1,Y1
P2      = POINT/X2,Y1
SETPT   = POINT/X,Y
L1      = LINE/P1,P2
L2      = LINE/P2,PERPTO,L1
L3      = LINE/P1,PERPTO,L1
          TERMAC

Press any key to continue...
```

```
123456 8 10                       7273          80
TOOL    = MACRO/ID,L,TN,DIA,N,A
          TOLNO/ID,LENGTH,L
          SELECTL/TN,LENGTH,L
          LOADTL/ID,TN
          CUTTER/DIA
          SPNDL/RPM,N,CCLW
          COOLNT/A
          TERMAC

Press any key to continue...
```

```
123456 8 10                          7273         80
THR     = MACRO/P,DCUT,XDS,YDS,XD,YD
          THREAD/TURN,MMPR,P,DEPTH,DCUT
          FROM/SETPT
          RAPID
          GODLTA/XDS,YDS
          GO/TO,L1,TO,L3
          GOLFT/L1,TO,L2
          GODLTA/XD,YD
          RAPID
          GOTO/SETPT
          TERMAC

Press any key to continue...
```

Table D-2(b)

```
123456 8 10                              7273        80
PARTNO     AXIAL DRILLING
         CLPRINT
        . MACHIN/ 212
X       =    105.000
Y       =      0.000
XS      =    100.0000
YS      =      0.0000
DX      =     20.0000
XDS     =      3.000
YDS     =      0.000
XD      =      0.000
YD      =      0.000
LEN     =   103.000
D       =    22.000
SPEED   =   1446.8600
FEED    =    361.7200
COOL    =   ON
TOLID   =   01
TOLNO   =   01


Press any key to continue


123456 8 10                                          7273 80
         CALL/SET,X = X,Y = Y
         CALL/TOOL,ID = TOLID,TN = TOLNO,L = LEN,$
         DIA = D,N = SPEED,F = FEED,A = COOLEN
         CALL/DRILL,X1 = XS,Y1 = YS,DX = DX,$
         XDS = XDS,YDS = YDS,XD = XD,YD = YD
         COOLNT/OFF
         SPNDL/OFF
         FINI
```

TABLE D-2 (c)

(Contd...)

```
123456 8 10                                    7273         80
SET      = MACRO/X,Y
SETPT    = POINT/X,Y
           TERMAC

Press any key to continue...
```

```
123456 8 10                                  7273         80
TOOL  .  = MACRO/ID,L,TN,DIA,N,F,A
           TOOLNO/ID,LENGTH,L
           SELECTL/TN,LENGTH,L
           LOADTL/ID,TN
           CUTTER/DIA
           SPNDL/RPM,N,CCLW
           FEDRAT/MMPM,F
           COOLNT/A
           TERMAC

Press any key to continue...
```

```
123456 8 10                                7273         80
DRILL    = MACRO/XDS,YDS,XD,YD,X1,Y1,DX
           FROM/SETPT
           RAPID
           GODLTA/XDS,YDS
           GOTO/X1,Y1
           GODLTA/-DX,0
           GODLTA/DX,0
           GODLTA/XD,YD
           RAPID
           GOTO/SETPT
           TERMAC

Press any key to continue...
```

Table D-2(c)

Table D-2(a,b,c) Sample part programs and macros.

APPENDIX - E

USER'S MANUAL

This appendix gives the user necessary instructions to run the software package for process planning and NC-part program generation for rotational components.

The following commands are to be used for running this program. It is to be noted that the user must be in possession of the floppy disc which contains the above mentioned package. The capital lettered commands are to be input by the user.

C > CD DBASE

C > DBASE

(you are now in DBASE-III plus dot prompt)

. SET DEFA TO A:

(This command takes you to floppy drive)

. DO MENU

(You are now in main menu of Module-I)

During the process planning session the program asks the user to input information for selecting operation, machine tool, work material, toolholder, insert, work piece attributes, cutting conditions and turret location, by invoking menu options from 1 to 9. These options are to be selected in their serial order. After the process plan is generated, the user quits this menu by invoking option 10.

The following command takes you to the module-II.

. DO PART

This program asks you whether you have already used the first module. You have to answer Y (yes) or N (no). Remember for affirmative or negative answers the return key is not to be pressed. If module-I is not used earlier, then process planning information along with the part programming information is to be inputted in this session. The user selects options from 1 to 4 for generating the part program and option 5 is to be used for quiting this menu.

For editing or appending the information stored in database, regarding machine tools, cutting tools (toolholders and inserts), work materials, tool materials and cutting fluids the command is:

. DO NEW

You have to select one of the options from 1 to 6 for adding a new machine tool, work material, tool material, cutting fluid, toolholder and insert record respectively. Option 7 is to be used for quitting this menu.

The deleting of records pertaining to machine tools, toolholders, inserts and work materials is accomplished by:

. DO DELETE

The menu options from 1 to 4 are to be used for deleting an existing record for machine tool, work material, toolholder and insert respectively. Option 5 is to be used for quiting this menu.

You can quit the DBASE directory by

. QUIT

This takes you back to the root directory of the hard disc.